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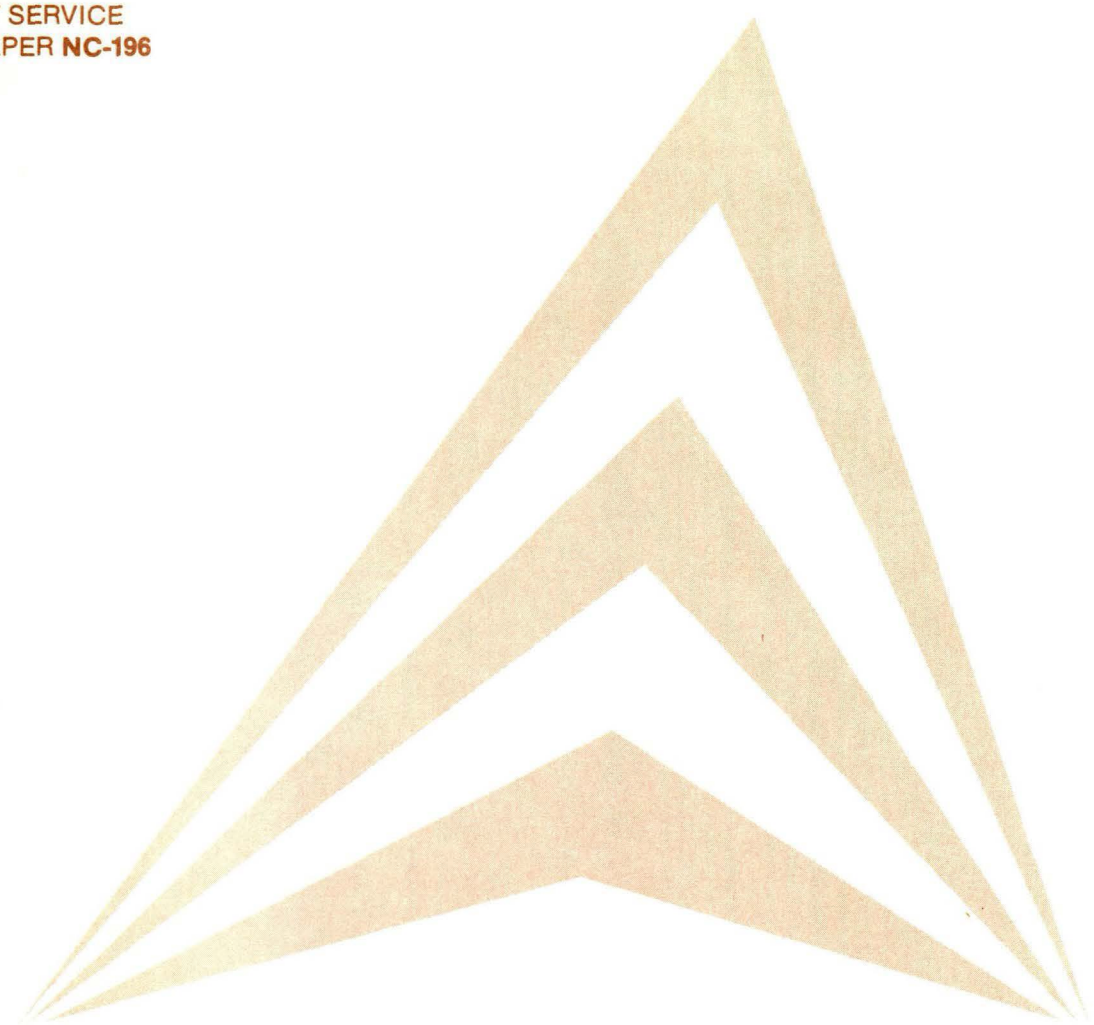

An economic and energy analysis of poplar intensive cultures in the Lake States

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AN ECONOMIC AND ENERGY ANALYSIS OF POPLAR INTENSIVE CULTURES IN THE LAKE STATES[1]

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Interest in the use of intensive silviculture to produce high yields of wood fiber in short rotations has been increasing. This trend is not really a result of foreseen shortages in hardwoods—nationally, hardwood removals are still well below growth (USDA Forest Service 1973)— but instead reflects an increased awareness of the potential economic advantages of growing wood fiber intensively. Through concentration of high yields in small areas close to the mill or plant, intensive short-rotation culture might remove many of the uncertainties connected with fiber supply from small private woodland and public land. It would also reduce hauling costs, an increasingly important consideration due to the energy situation. The actual application of short rotation intensive wood production systems to supply biomass for energy, fiber for pulp mills, or both, will depend on the economic and energy efficiencies of alternative production systems available for producing wood biomass.

The purpose of this paper is to present a close look at the economic and energy efficiencies of intensively growing hybrid poplar in the Lake States in a manner likely to be used by industrial users of wood fiber. Realistic information with respect to all the relevant production costs and biological growth response information are becoming increasingly available. Thus our intent is to make as specific an analysis as possible without having a particular firm or location in mind, in an attempt to help bridge the gap between theory and practice in intensive silviculture. Cash costs and returns of specific production systems are estimated in both dollar amount and relative uncertainty and are evaluated using cash flow techniques. The sensitivity of the investment performance measures (e.g., internal rate of return, net present worth) to various factors of production and yields is carefully evaluated. Detailed sensitivity tables are provided that will permit the manager or analyst to change values for any of the production factors and determine their impact on the financial performance. Thus we believe that this study may be of great utility in forest management planning and in further research. Energy requirements and outputs are estimated and contrasted with cash flows to identify critical cost/energy trade-offs.

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RECENT ECONOMIC INVESTIGATIONS OF INTENSIVE CULTURE SYSTEMS

An industry-wide survey was conducted in 1975 to evaluate trends of and needs for intensive culture on forest industry land and to determine potential impacts on future wood supplies (DeBell 1976, DeBell *et al.* 1977, Gansner *et al.* 1977). The survey showed that intensively cultured wood from industrial land is not expected to increase total annual wood harvest in the North by more than 2 percent in the next decade. Lack of knowledge on intensive culture and

the great uncertainties related to intensive management systems were major reasons that industries had not adopted intensive culture. Furthermore, many industries were not experiencing shortages of poplar supplies.

Several conferences on intensive silviculture during the last few years have brought together existing knowledge on the many different facets of intensive silviculture. But many uncertainties remain and only actual operational testing of specific alternatives can provide the final answer to many questions (Iowa State University 1975, 1976).

Several studies have dealt with economic questions of intensive cultures. DeBell and Harms (1976) identified cost factors associated with intensive culture of short-rotation forest crops. Their study showed that intensive silviculture will be expensive and therefore, must be evaluated carefully. Dutrow and Saucier (1976) reassessed the economic implications of short-rotation systems of coppicing sycamore for silage. They concluded that only industrial landowners would find production profitable.

Rose and DeBell (1978) in their analysis of intensive cultures emphasized the sensitivity of major investment performance measures to wide changes in costs and yields to obtain insight into the economic feasibility of intensive culture. Although the study revealed critical areas such as land cost, site preparation, planting, harvesting, and fertilization, that should be addressed before implementing an intensive culture system, it was not designed to provide conclusive answers. In other studies, Rose found that long-rotation alternatives offer better investment opportunities than short ones but that irrigation does not appear economical (Rose and Kallstrom 1976, Rose 1977).

Intensive silviculture has received attention recently as a possible way to produce large quantities of biomass for energy (Inman *et al.* 1977, Fege *et al.* 1979, Rose 1977, Zavitkovski 1979). However, much of the economic work in this area must be viewed with caution because the analyses deal with untested systems. Typically, assumptions concerning yield appear far too optimistic and various costs, especially harvesting, are probably much too low. One other major criticism is the lack of adequate sensitivity analyses to identify factors critical for economic production and to deal with questions of uncertainty that surround these untried production systems (Rose 1977).

STUDY DESCRIPTION

Scope

Many alternative methods for the intensive production of hybrid poplar are possible. The major variables of alternative systems are spacing, rotation length, and cultural practices (including site preparation, weed control, irrigation, and fertilization). Spacings have been proposed that range from 1 foot by 1 foot (0.3 m by 0.3 m) to 12 feet by 12 feet (3.6 m by 3.6 m). Proposed rotations range from 4 to 15 years.

In this study we evaluated four specific production systems that represent a range of spacings, rotations, and cultural practices. Two spacings, 4 feet by 4 feet (1.2 m by 1.2 m) and 8 feet by 8 feet (2.4 m by 2.4 m), and three rotations, 5, 10, and 15 years, were chosen; irrigation and fertilization were treated as options, whereas site preparation and weed control were assumed the same for all four alternatives (table 1).

Table 1.—*Specifications for four intensive-culture alternatives*

Alternative	Spacing	Rotations	Origin of stands	Irrigation & fertilization	Yield[1]	
					(Dry tons/acre/year)	mt/ha/year
1	4 by 4 ft	(1) 10 yrs	cutting	yes	6.3	14.1
	(1.2 by 1.2 m)	(4) 5 yrs	coppice		7.2	16.2
2	4 by 4 ft	(1) 10 yrs	cutting	no	3.2	7.2
	(1.2 by 1.2 m)	(4) 5 yrs	coppice		3.6	8.1
3	8 by 8 ft	(1) 15 yrs	cutting	yes	6.3	14.1
	(2.4 by 2.4 m)	(1) 15 yrs	coppice			
4	8 by 8 ft	(1) 15 yrs	cutting	no	3.2	7.2
	(2.4 by 2.4 m)	(1) 15 yrs	coppice			

[1]Stem and branchwood, including bark. (See table 1, Appendix 1).

The size of operation for each alternative is 1,000 acres of cleared, marginal agricultural land arranged in 10 tracts of from 80 to 120 acres each. All 1,000 acres are put into production at the same time, i.e., the analysis does not deal with a sustained yield operation. The methods of site preparation, plantation establishment, and weed control are a combination of chemical and mechanical means and are the same for each alternative. The method of irrigation is a traveling gun system (one system per tract) that applies 10 inches per acre annually. Fertilization includes only nitrogen additions applied in liquid form through the irrigation water at an annual rate of 110 kg per hectare (100 lbs per acre). Harvesting methods are whole-tree chipping for the 10- and 15-year rotations, and forage-type mechanized harvesting for the 5-year coppice rotations. Financial considerations common to all alternatives are administrative costs, insurance, land purchase and sale, equipment costs, and taxes (property and income). An annual inflation rate of 5 percent and a discount rate of 10 percent are applied to all costs and returns (Appendices 1 and 2 give a complete explanation of the inputs and outputs of the alternative production systems).

Methods

Specific inputs and outputs (both physical and monetary) of each productive system were identified through consultation with the USDA Forest Service researchers at the North Central Forest Experiment Station, Forestry Sciences Laboratory, in Rhinelander, Wisconsin, and with the forester in charge of what is currently the only industrial large-scale application of hybrid poplar intensive culture in the Lake States, in Filer City, Michigan. Along with dollar estimates of each cost and return (Appendices 1 and 2), an estimate was made of the relative uncertainty of each cost and return item (Appendix 1).

Costs and returns for each alternative system were evaluated for a 30-year period using simple cash flow techniques (Appendix 2).

Direct energy inputs and outputs were evaluated in two ways: (1) using cash flow methods, substituting energy units for dollars and discounting future energy flows at 10 percent annually, and (2) directly comparing inputs and outputs without discounting the future. Our rationale for discounting energy flows is that it represents a means for comparing the timing and risk involved in using energy inputs of known practical value (petroleum, electricity) for different energy production schemes. For example, a barrel of oil can be invested today into producing more energy in the form of equipment for mining or for growing trees. Certainly the timing and risks of energy outputs for the same energy inputs are different and need a common basis for comparison. For the benefit of those who do not agree with this rationale, energy inputs and outputs are also compared without discounting (Appendices 3 and 4).

RESULTS

Investment Performance Measures

At the assumed 10 percent discount rate, none of the alternatives have a positive net present worth (table 2). The two systems using irrigation and fertilization have negative internal rates of return, and the two systems that do not use irrigation or fertilization have after-tax rates of return of 8.1 percent (Appendix 2). Economically, the difference between short (5 to 10 years) and long (15 years) rotation alternatives is small but the difference between irrigated and nonirrigated alternatives is large.

Sensitivity Analysis

Sensitivity analysis is a valuable tool for predicting the potential effect of changes in uncertain estimates of costs and returns (Appendix 1 gives a complete explanation of how to interpret sensitivity analyses).

The sensitivity analyses in the cash flows (Appendix 2) can be used to identify the uncertain factors that will critically affect net present worths (NPW) and internal rates of return (IRR). It can also be used to identify conditions under which intensive cultures might be economically attractive.

In each of the alternative systems, the most important estimate affecting investment performance measures is product sale value. For the irrigated systems, a 10 to 12 percent change in product sale value could change the IRR by 2 percent; for the nonirrigated systems, an 18 to 22 percent change would do the same. Product sale value has two components— yield and market price. A change in either one or both from what is estimated could substantially change the economic attractiveness of an investment in hybrid poplar, and such changes are

Table 2.—*Investment performance of four intensive-culture alternatives*

Alternative	Description	Internal rate of return	Net present worth
		(percent)	($/acre)
1	4- by 4-foot (1.2-m by 1.2-m) spacing, irrigated and fertilized, short rotations (5 to 10 years)	–0.4	–2003.82
2	4- by 4-foot (1.2-m by 1.2-m) spacing, not irrigated or fertilized, short rotations (5 to 10 years)	8.1	–236.78
3	8- by 8-foot (2.4-m by 2.4-m) spacing, irrigated and fertilized, long rotations (15 years)	–1.6	–2149.51
4	8- by 8-foot (2.4-m by 2.4-m) spacing, not irrigated or fertilized, long rotations (15 years)	8.1	–200.30

likely. The most likely direction of change in yield is downward (see the discussion on risks, below). The direction of change in the market prices for whole-tree chips 10 to 30 years from now is a matter of speculation.

Irrigation operating costs are next in importance for the irrigated systems. They would have to be substantially reduced, however, to make these projects look even remotely attractive. Because a large part of the cost of operating a traveling gun irrigation system is due to fuel, a substantial cost reduction in this irrigation system in the future is unlikely. The only way reduction in irrigation costs appears likely is to use different irrigation technology (trickle irrigation), only irrigate during the first few years of each rotation, or irrigate a lesser amount each year which would likely reduce yields and perhaps cancel out the effect of cost reductions through reductions in product sale value. Irrigation equipment costs are of some importance but to a lesser degree than operating costs.

Our cost estimates for irrigation were derived in coordination with the University of Minnesota Agricultural Extension specialist for irrigation and are believed to be valid for Minnesota operations. It is known, however, that large differences can occur from one region to another and between different irrigation systems and power units. Sheffield (1979) compared both the fixed and variable costs for the four major types of power units used for irrigation pumping plants and found that natural gas is the most economical source of irrigation pumping. Electricity is the second most economical source. Sheffield (1979) points to a recent shift to propane or LPG (Liquid Propane Gas), a by-product of the oil refining process, that has shown relatively stable prices in recent months. Diesel fuel is the most expensive way to irrigate, but nonetheless is the most widely used in the Lake States.

Reductions in the variable cost of up to 20 percent appear possible by switching to electric and propane fuel sources and reductions of possibly 50 percent by switching to natural gas. Fixed costs also might be reduced as much as 50 percent by switching to electric power, if power lines are available at the irrigation site.

If costs could be reduced 50 percent both in the variable as well as fixed cost components of irrigation, it would not make NPW positive although it would increase NPW for both irrigation alternatives by $1,135.50. A thorough analysis of the circumstances for irrigation is essential in each specific production situation.

Harvesting, especially whole tree harvesting, is a significant cost for all systems. Roughly a 20 to 40 percent change in harvesting costs would change the rate of return by 2 percent for the long rotation systems because they would use only the whole-tree method. Forage-type mechanized harvesting costs, though much more uncertain, are not nearly as important to the financial appearance of the short rotation alternatives. Both types of harvesting employ new technology and their costs depend on many variable stand and terrain factors, which makes future cost predictions difficult. However, even though these costs are uncertain, they are important to the economic performance of any hybrid poplar investment.

The other uncertain estimates—fertilization, land sale value, and income tax—do not significantly affect investment performance.

Energy Flows

Energy output was measured in terms of **gross heat value**, which does not account for losses during conversion of the biomass into other forms of energy. Discounted and nondiscounted energy flows were used to calculate energy output/input ratios (table 3). The two irrigated systems have lower output/input ratios than the two nonirrigated systems. (Details on the energy analysis in terms of energy inputs and outputs are found in Appendix 3.)

These comparisons are valid for the specific assumptions of this analysis. If, for example, fertilization and associated energy inputs are considered necessary for nonirrigated systems, the nondiscounted energy output/input ratios would drop. Naturally, yields or energy outputs might also increase and counteract a decline in the ratios. For irrigated systems energy inputs for irrigation might be lower because of an alternative system used or a less intensive irrigation schedule. For example, a 50 percent reduction in irrigation energy inputs would increase the energy output/input ratios by about 0.45. Under both conditions, i.e., need for fertilization in nonirrigated crops and lower irrigation energy inputs, irrigated and nonirrigated systems would be about equally energy efficient.

DISCUSSION

A Proper Perspective in the Economic Evaluation of Intensive Culture Investments

From the viewpoint of an industrial user of wood, the economic performance of an investment in hybrid poplar does not mean much in isolation, but must instead be compared with alternative investments in other sources of supply. The real value of intensive culture is not its return on investment (though for nonirrigated systems, an 8 percent after-tax return is not bad compared to other forestry investments), but its ability to provide a secure source of supply to a mill or plant that would be very costly to shut down. For a particular firm, its location, access to wood supplies (including present or potential environmental regulations and restrictions), and the amount of competition it must face for the wood supply are more important factors to consider than the economic performance measures of intensive culture investments, although these can be used as guides in choosing between particular investment opportunities.

Table 3.—*Net present worths (NPW) and output/input (O/I) ratios of energy flows under two discount rates (10 percent and 0 percent), when energy output is the gross energy value of wood*

Alternative	Description	Net present worth (MMBTU's/acre)[1]		Output/input ratio[2]	
		10 percent	0 percent	10 percent	0 percent
1	4- by 4-foot spacing, irrigated and fertilized, short rotations (5 to 10 years)	453.42	2,346.82	2.62	3.08
2	4- by 4-foot spacing, not irrigated or fertilized, short rotations (5 to 10 years)	285.08	1,362.00	4.50	4.61
3	8- by 8-foot spacing, irrigated and fertilized, long rotations (15 years)	251.60	2,129.80	2.15	3.04
4	8- by 8-foot spacing, not irrigated or fertilized, long rotations (15 years)	184.74	1,254.10	4.64	4.76

[1]Net present worth at 0 percent discount rate equals the sum of the returns minus the sum of the costs. Net present worth at 10 percent discount rate obtained from energy flow analysis in Appendix 4.

[2]Output/input ratio at 0 percent discount rate equals the sum of the returns divided by the sum of the costs. Output/input ratio at 10 percent discount rate obtained from investment performance measures in Appendix 4.

Risks and Uncertainties of Intensive Fiber Production

High yields are the most attractive feature of intensive culture systems. Any reduction in yield is therefore significant and deserves careful consideration in any decision regarding investment in intensive culture systems. Yields may be lower than we have predicted for three major reasons: (1) yield data have been reported only for carefully tended research plots grown for short periods, not for long-term operations; (2) risks from insects and disease damage are significant— they may reduce annual growth or even destroy entire portions of a crop; (3) yields for nonirrigated, nonfertilized crops are speculative because little data are available. The lack of irrigation and fertilization may reduce annual growth, as we have assumed, or may make the difference between success or failure of the crop during the establishment period. Yields from nonirrigated crops are no more or less certain than those from irrigated crops; insects and disease are probably the greatest sources of risk, whether the crop is irrigated and fertilized or not.

According to some experts in the field, fertilization is a must for short-rotation intensive culture. If we applied the fertilizer regime described for the irrigated alternatives to the nonirrigated production alternatives, NPW would be reduced by about $200/acre. An offsetting increase in yield may occur, however. With all other assumptions unchanged, this would not change the ranking of the alternatives. In combination with other changes such as the discussed lower cost irrigation alternatives, the ranking of the alternatives could conceivably change in favor of the irrigation alternatives. This, however, does not make them financially attractive.

Even small yield reductions can have substantial impacts on returns and the overall economic performance of an intensive culture project. Uncertainty about yields combined with other financial uncertainties (irrigation and harvesting costs and market value of the product) that can affect economic performance, means that an investment in the intensive culture of hybrid poplar must be regarded as having substantial risk and evaluated accordingly.

Irrigation and Fertilization

Even with optimistic yield estimates, irrigation and fertilization are economically unattractive due largely to the high cost of operating irrigation equipment. Fertilization may be an economical way to increase yields, though from our analyses this is difficult to evaluate because the method of application is not included in its cost. Irrigation, however, seems to be clearly uneconomical.

Nor is irrigation energy efficient. The net energy value when energy output is measured as gross or usable energy is higher for irrigated systems, but the output/input ratio, a measure of efficiency, is lower. In terms of using wood fuel to produce electrical energy, irrigated systems produce only a little more energy than they use in the production process.

Not irrigating means lower yields. However, other things being equal, nonirrigated yields would have to be reduced to less than 10 percent of irrigated yields (roughly ½ dry ton/acre/year) before the NPW of nonirrigated systems would decline to that of irrigated systems. This is not likely. On the other hand, not irrigating would make site selection more important to avoid losing an entire crop due to drought during the establishment period. And such sites might be more expensive.

If irrigation costs can be reduced 50 percent or more by switching to other types of power or by irrigating less frequently, the irrigated systems would more closely compete economically with nonirrigated systems.

Situations might exist in which larger blocks of land can be obtained. Each traveling irrigation gun system can handle up to about 300 acres so the fixed cost could possibly be reduced by 67 percent. However, this reduction, even in combination with a substantial reduction in the variable cost of irrigation, would still not make the irrigated alternatives more attractive than the nonirrigated ones.

Short vs. Long Rotations

The short- (5 to 10 years) and long- (15 years) rotation alternatives we have looked at differ little in terms of economic return and energy efficiency. Each has advantages and disadvantages. Short-rotation production systems return revenues sooner and more frequently. The wood can be harvested with forage harvesting methods that are as yet undeveloped but may be less expensive than traditional methods. The crop is carried for shorter periods of time so the risk of losing a crop is not as great nor would the loss be as severe. Short rotations also allow managers to more quickly incorporate yield improvements, resulting from new genetically improved hybrids, into the plantation operation. However, the type of wood produced may not be usable for all purposes because it

contains more juvenile wood and bark than conventional chips. Long-rotation crops produce wood of a more conventional form that can be harvested with proven methods. Planting costs are much lower, but the crops must be carried for long periods so revenues are returned later and less often than with short-rotation crops.

Any initial decision about short or long rotations can be changed as questions are answered about insect and disease risks, uses for wood fiber from young trees, and harvesting technology. Flexibility in rotation length is one advantage of growing wood because it is a crop that can be stored on the stump.

Economies of Scale

The cost estimates used in our analyses were for the most part variable, which does not allow us to make a quantitative estimate of how the overall investment might look on a different scale of operation. We examined investment alternatives as solitary projects, not as sustained yield operations, as would be the most likely practice. For a sustained yield operation of this size (planting 1,000 acres per year), overhead costs such as administrators, full-time employees, a nursery, equipment storage and repair, etc., would certainly increase. However, the most important costs and returns in terms of overall economic performance (product value and harvesting) would not change.

Another important consideration, whether the operation is viewed as sustained yield or not, is the size and distribution of tracts. One large block of 1,000 acres would be less costly to prepare, plant, harvest, and irrigate, though such a block of land near a mill and for sale would be difficult to find in the Lake States. The location of tracts, in relation to each other and to the mill, is probably more important than their individual sizes, because this would affect costs of moving equipment (site preparation, planting, and harvesting) and administration. Economical tract sizes would depend primarily on harvest costs because (1) these are significant in the overall economic outlook of a project, and (2) certain fixed costs of putting in landings and skid roads are necessary for every tract regardless of size.

Cost/Energy Trade-offs

Nonirrigated systems are more energy efficient and also more economical under the assumptions made than irrigated systems so no trade-off is involved. If gross energy is of concern, cost/energy trade-offs could be made (table 3).

Our view is that energy efficiency is the more important criterion. Producing wood biomass without irrigation (and fertilization) is more energy-efficient *and* economical. The short- (5 to 10 years) and long- (15 years) rotation alternatives (both nonirrigated) differ little either in economic performance or energy efficiency.

CONCLUSIONS

Intensive culture of hybrid poplars in the Lake States with our estimates carries substantial risks and does not yield high monetary returns. Intensive culture projects are primarily of interest to industrial users of wood fiber, who can compare them with other sources of supply before making investment decisions.

Nonirrigated production strategies are recommended as long as users find our assumptions about irrigation regimes, costs, and obtainable land tract sizes acceptable. Under the conditions specified, irrigating hybrid poplar does not appear economical nor energy efficient.

Short- (5 to 10 years) and long- (15 years) rotations differ little in terms of economics and energy efficiency. In view of the uncertainties of some costs and returns that may dramatically affect the economic outlook of a project (specifically, product value, irrigation, need for fertilization, and harvest costs), any initial decision about rotation length for a particular project should be regarded as tentative. If a careful site-specific investigation into irrigation technology and costs and available tract sizes can reveal a more favorable cost picture than we assumed, irrigation alternatives could be more attractive.

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APPENDIX 1.— DETAILS OF CASH FLOW ANALYSIS

The following discussion details and documents the assumptions and numbers used in our analysis of alternative investments in hybrid poplar plantations. After the discussion of cash flow methodology and basic assumptions about the projects, an explanation of each item in the cash flow printouts is given (Appendix 2). Those interested in these details may not agree with every estimate, but should find it easy to understand our reasoning, to make changes, and to assess the effect of these changes through the sensitivity analysis tables.

Cash Flow Methodology

The various intensive culture alternatives were analyzed using cash flow analysis and charted in cash flow tables (Appendix 2). The cash flow table is primarily a listing of the amounts of costs and benefits for each year in the production period. In addition, the cash flow presents the total costs, total benefits, and net benefits for each year. The table, therefore, contains the data necessary to calculate several measures of project performance. Given a specified discount rate, four useful intermediate measures can be calculated and included in the cash flow table: discounted net benefits, cumulative discounted net benefits, discounted costs, and cumulative discounted costs. The above measures are listed in the bottom four rows of the cash flow tables generated by the program.

These four intermediate measures are used to calculate several of the investment performance measures described below. Each discounted net benefit equals the net benefit figure for that year (year y) divided by
$(1 + i)^{y-b}$, where:

- i = the rate of discount,
- y = the year in which the net benefit occurs, and
- b = the beginning year of the project (initial year of investment).

Each **cumulative** discounted net benefit equals the sum of the discounted net benefits for all years up to and including that year (year y). Each discounted cost and cumulative discounted cost is determined in exactly the same way as discounted net returns and cumulative discounted net benefits, respectively, except that the total cost row is used instead of the net benefit row. Cumulative discounted net benefits show the incremental yearly totals of discounted net benefits. The final yearly total equals the net present worth. Cumulative discounted costs show the present value of all costs up through the column year. When using the cost-price analytical approach described below, the value of the cumulative discounted costs is important.

Investment performance measures

The four investment performance measures calculated by the program are defined as follows:

(1) **Internal rate of return (IRR)** is the rate of discount that makes the present value of benefits equal the present value of costs, i.e., the rate that makes NPW equal zero.

$$\sum_{y=b}^{e} \frac{B_y}{(1+IRR)^{y-b}} = \sum_{y=b}^{e} \frac{C_y}{(1+IRR)^{y-b}}$$

(2) **Net present worth** (NPW) is the sum of the discounted net benefits for one production period.

$$NFW = \sum_{y=b}^{e} \frac{(NB)_y}{(1+i)^{y-b}}$$

(3) **Net future worth (NFW)** is the sum of the compounded net benefits for one production period.

$$NFW = \sum_{y=b}^{e} (NB)_y\,(1+i)^{e-y} = NPW\,(1+i)^{e-b}$$

(4) **Benefit-cost (B/C)** is the ratio of the total discounted (gross) benefits and total discounted costs.

$$B/C = \frac{\sum_{y=b}^{e} \frac{B_y}{(1+i)^{y-b}}}{\sum_{y=b}^{e} \frac{C_y}{(1+i)^{y-b}}}$$

Where:

- b = the beginning year of the project (initial year of investment),
- e = the ending year of the project (last year of benefits or costs),
- i = the rate of discount,

y = the year designation representing the individual years between year b and year e, inclusive,
B_y = total benefits in year y,
C_y = total costs in year y, and
$(NB)_y$ = net benefit in year y, equals $B_y - C_y$.

Future cost (FC) equals the future value of all project costs and is also calculated by the program although it is not directly an investment performance measure. Future cost is calculated by multiplying the cumulative discounted costs for the last year (year e) by $(1+i)^{e-b}$. Another method of calculating FC is as follows:

$$FC = \sum_{y=b}^{e} C_y (1+i)^{e-y}$$

Sensitivity analyses tables

A desirable procedure in any investment analysis is to examine how sensitive various measures of project performance are to changes in costs, prices, interest rates, and other inputs, e.g., machine production rates, time constraints on a silvicultural activity, etc. The reason for such sensitivity analyses is that most estimtes of inputs and outputs are interval rather than point estimates. In other words, individual estimates have errors associated with them that might be expressed by putting limits of confidence around them. Knowledge of the sensitivity of an investment to the various factors is an essential part of the assessment of the risk associated with the investment. It gives valuable insights into what might happen if yields, prices, and/or costs turned out differently than expected. Two types of sensitivity analyses are carried out within the program automatically. Various points will be illustrated on the nonirrigated 4- by 4-foot plantation.

First sensitivity analysis table (Appendix 2)

The first sensitivity analysis table shows changes in NPW due to a percentage change (increase or decrease) in each benefit and cost. The magnitudes of the changes in NPW indicate the impacts of changes in the costs and benefits. The larger the number in a given column, the greater the impact resulting from a given percentage change. In our example the greatest impact would result from changes in product sales and the least impact from changes in administration and site preparation costs. In addition to impacts on the investment performance measures, specific impacts can also be calculated. For example, NPW for the nonirrigated 4- by 4-foot plantation was –$236.78. If forage harvesting cost decreased by 10 percent, NPW would be –$215.97 (–$236.78 + $20.81). On the other hand, if forage harvesting cost **increased** by 10 percent, NPW would be –$257.59 (–$236.78 – $20.81). Cost increases and benefit decreases of 10 percent **decrease** the four investment performance measures by the amounts indicated in the table, and cost decreases and benefit increases of 10 percent **increase** the measures by the same amounts. Furthermore, changes in NPW resulting from changes in costs and benefits other than 10 percent can be calculated directly from the table. For example, a 50 percent increase in land cost would lower NPW by five times the amount of a 10 percent land cost increase (five times $40 or $200).

Combinations of any number of changes in the costs and benefits can be calculated. For example, if all costs were assumed to be 10 percent higher and all benefits 20 percent higher, NPW would be –$128.20 (–$236.78 – $155.94 + $264.52). In other words, even if the above cost and benefit changes occurred, the investment decision would remain the same because the decision switching value occurs when NPW equals zero.

Sometimes it is useful to know how much change is necessary in one or more costs and benefits to change the investment decision. In the example, one might wish to know by how much product sales values must increase to cause the project to be accepted. This is determined by dividing NPW by the corresponding change in that measure (from the first sensitivity table), and then multiplying the result by the percent change specified in the table (10 percent in the example). Using NPW the result is the following:

$\frac{-\$236.78}{\$114.81} = 2.06$ or a 20.6 percent increase of product sales value would make NPW = 0 and IRR = 10 percent.

Second sensitivity analysis table (Appendix 2)

The second sensitivity analysis table shows the percent changes in activities (costs and benefits) necessary to raise and lower IRR and NPW by specified amounts. This sensitivity table is of most interest when the IRR is close to the specified discount rate. In this case, it is valuable to know how likely it would be that the investment return could be above or below a desired rate of return. For the nonirrigated 4- by 4-foot plantation case presented in Appendix 2, the specified changes were 2 percent in IRR and $236.78 in NPW. As in the case of the first sensitivity table, the activities are listed in the first column. Columns

2 and 3 show the percent changes in each activity necessary to raise and lower IRR by 2 percent. Columns 4 and 5 similarly show the percent changes in each activity necessary to raise and lower NPW by $236.78. It is apparent in this case that changes in product sales and land cost have the greatest influence on IRR and NPW. For NPW the same percent change is always required to raise and lower the measure by an equal amount—only the sign changes. However, the percent changes necessary to raise and lower IRR by the same percentage amount are seldom equal. Similarly, the additive and multiplicative advantages associated with sensitivity testing of NPW are not applicable to sensitivity testing of IRR. Just because a 22 percent increase in product sales increases the IRR by 2 percent in the example, a 44 percent increase will not necessarily increase IRR by 4 percent. Yet, because a 21 percent increase in product sales will increase NPW by $236.78, a 42 percent increase **will** increase NPW by $473.56. Therefore, it is clear that such sensitivity testing for simultaneous changes in several activities is better performed using NPW than IRR.

Basic Assumptions

Inflation

We chose a 5 percent annual inflation rate, because economic forecasters have predicted this as an average long-term rate. You will note three exceptions to this rate in the cash flow printouts: (1) land resale value, which we estimate will increase more rapidly than other prices (we have said 7 percent annually), (2) income tax, which already takes inflation into account because it is calculated from income and costs in the years they occur, and (3) irrigation equipment insurance, which we assumed to remain constant for a given group of equipment thus declining in real terms to reflect the declining value of aging equipment.

Discount rate

A 10 percent discount rate was used in each cash flow analysis based on an estimated cost of capital. We think a discount rate based on opportunity cost or risk should be accounted for at other stages of the decision making process.

Rotations

For the 4- by 4-foot spacing, the first rotation is 10 years and the four subsequent coppice rotations are 5 years. For the 8- by 8-foot spacing, both the initial and coppice rotations are 15 years. Total project length is 30 years.

Yields

Stem and branch wood dry biomass measured in tons is the unit of product yield. Biomass rather than roundwood is considered because the expected end uses of intensively grown wood are pulp and fuel. Yields for irrigated, fertilized, first-rotation crops were adapted from Ek and Dawson (1976) and are optimistic. Yields for nonirrigated, nonfertilized crops will likely be at least 50 percent less. Yields for the 5-year coppice rotations will be roughly 1¾ times the yields for 5-year first-rotation crops. We expect that this growth increase will be notable only in the first few years. Thus, the yield for the 15-year coppice rotation will be similar to the first rotation (table 4). Total project acreage is larger than the total acreage planted in most cases because some will always be lost to roads, powerlines, swamps, etc. For the analysis, the yields per planted acre had to be spread over total project acreage and are, therefore, smaller for the latter.

We did not include insect and disease control in the costs and returns. Although control measures would almost certainly be needed at some point in an operation of this size and length, we did not include their costs because they are difficult to estimate, both in amount and timing, and because we feel they are best evaluated as risks in the same way as fire and other uncertainties by making adjustments in the harvestable yields.

Explanation of Cash Flow Cost and Return Items

Site preparation and establishment activities considered

Site preparation of already cleared land for this hypothetical plantation includes plowing, disking, and applying a preplanting herbicide (Round-up and Simazine). All these activities take place the late summer or fall prior to spring planting. For the 4- by 4-foot spacing, 3 lbs. of Round-up and 2 lbs. of Simazine/acre are applied in a broadcast application using a tractor-pulled sprayer. For the 8- by 8-foot spacing, the chemical is applied in 3-foot strips using the same equipment. Trees are later planted in these strips.

Table 4.—*Yields of stem and branch wood for four production alternatives*

Spacing	Irrigated	Rotation	Yield of stem and branchwood at end of rotation			
			Dry tons/ planted acre	*mt/ planted ha*	*Dry tons/ project acre*	*mt/ project ha*
4- by 4-ft	Yes	1st (10 yrs)	70	157	63	141
(1.2 by 1.2 m)		2nd (5 yrs)	40	90	36	81
		3rd (5 yrs)	40	90	36	81
		4th (5 yrs)	40	90	36	81
		5th (5 yrs)	40	90	36	81
4- by 4-ft	No	1st (10 yrs)	35	78	31.5	71
(1.2 by 1.2 m)		2nd (5 yrs)	20	45	18	40
		3rd (5 yrs)	20	45	18	40
		4th (5 yrs)	20	45	18	40
		5th (5 yrs)	20	45	18	40
8- by 8-ft	Yes	1st (15 yrs)	105	235	94.5	212
(2.4 by 2.4 m)		2nd (15 yrs)	105	235	94.5	212
8- by 8-ft	No	1st (15 yrs)	52.5	118	47.25	106
(2.4 by 2.4 m)		2nd (15 yrs)	52.5	118	47.25	106

Postplanting establishment activities are cultivation (3 times) using a 20-foot Lilliston[2] cultivator, and a fall and spring treatment of Simazine, applied in the same way as the preplanting Round-up and Simazine treatment.

These methods are not put forth as the one best prescription to follow in raising hybrid poplar but only to explain the derivation of site preparation costs. This sequence was recommended by researchers at the North Central Forest Experiment Station, Forestry Sciences Laboratory in Rhinelander, Wisconsin, and by the Intensive Forestry manager at Packaging Corporation of America as being one method of growing poplar.[3] In practice, a variety of treatments would be used, depending on site conditions. Some additional or substitute treatments we did not consider are liming, spring disking, additional cultivations, cover crop seeding for controlling vegetation, and different types of chemicals. Also, we assume that no additional treatments will be necessary after the first rotation because the rapid initial growth of a coppice crop should be sufficient to stay ahead of the weeds.

[2]*Mention of trade names does not constitute endorsement of the products by the USDA Forest Service.*

[3]*Personal communication with M. Morin, Packaging Corporation of America, Filer City, Michigan.*

As shown in the following tabulation we have rated each cost and return item as to how accurate we feel our estimates are.

Cost/return item	Uncertainty of estimate	Comment
Site prep., establishment (operating costs)	Fairly certain	—
Planting (operating costs)	Fairly certain	—
Irrigation (operating costs)	Fairly uncertain	Estimates are reliable for the near future only.
Fertilization	Fairly certain to uncertain	Depends on the type of fertilizer and method of application. Estimates are reliable for near future.
Whole-tree harvest	Uncertain	Uncertainty primarily due to distance in the future and yield. No harvest experience with intensive culture stands.
Forage harvest	Extremely uncertain	Uncertainty due to both lack of information and distance in future.
Land cost	Fairly certain	Depends on location.
Administrative	Fairly certain	Depends on scale of operation.
Irrigation equipment	Fairly certain to uncertain	Good estimates available for initial investment only, not future replacement.
Site prep., planting, estab. equipment	Fairly certain	Depends on how cost is accounted for.
Insurance	Fairly certain	—
Income tax	Uncertain	Depends on interaction of all cost and return items.
Property tax	Fairly certain	Estimates reliable for near future only.
Investment tax credit	Fairly certain	Depends on price of irrigation equipment (see above).
Product sale	Very uncertain	Uncertainty due to yields and future prices.
Land sale	Uncertain	Rate of inflation, future markets unknown.

Operating costs

Only variable costs—labor, fuel, repair, and materials—are included. Fixed equipment costs are treated separately. Because only 90 percent of the available acreage in this hypothetical plantation is workable, 900 acres are used as a basis for calculating costs. Total site preparation costs are calculated as follows: for each operation, labor, fuel, and repair costs per hour are multiplied by the time needed to work 900 acres. (Time = 900 acres divided by the production rate in acres/hour.) Time spent moving between tracts and for employee breaks is included in the production rate. Material costs/acre are multiplied by 900 acres and added to the total labor, fuel, and repair costs to give the total cost for the operation. This is divided by 1,000 project acres to give a cost/acre (table 5).

Labor costs are $6/hour for equipment operators and $4/hour for planting crews. Repair costs are based on the American Society of Agricultural Engineers' estimates of total lifetime repair costs for farm equipment (table 6). We estimated diesel fuel consumption for tractors at 0.044 gal/hp and cost at $1/gal. Current prices for Round-up and Simazine are $60/gal (4 lbs/gal) and $2.40/lb, respectively.

Planting

Ten inch unrooted cuttings purchased at $80/thousand are planted in the spring using Holland planters and large tractors. For the 4- by 4-foot spacing, 2,600 trees/plantable acre are planted at a rate of ¾ acre/hour; for the 8- by 8-foot spacing, 650 trees/plantable acre are planted at a rate of 2 acres/hour. We have estimated that about 95 percent of the plantable acreage would be planted, the 5 percent loss being due to row ends, rocks, low spots, etc. To finish planting in a reasonable length of time (maximum 10 weeks) would require 3 tractors and 6 planters for the close spacing and 2 tractors and 4 planters for the wide spacing. Overtime would probably be necessary for the close spacing, though we have not accounted for it.

Table 5.—*Operating costs for site preparation*

Year	Operation	Equipment costs			Production rate	Total hours[4]	Material cost/ planted acre[5]		Total cost for operation		Cost/acre	
		Labor	Fuel[1]	Repair[2]			4- by 4-ft	8- by 8-ft	4- by 4-ft	8- by 8-ft	4- by 4-ft	8- by 8-ft
		-----Dollars/hour-----			*Acres/hour[3]*	*No.*						
0	Plow	$6.00	$9.90	$10.75	6.55	137.4	0	0	$3,662	$3,662	$3.66	$3.66
0	Disk	6.00	9.90	9.50	10.04	89.6	0	0	2,276	2,276	2.28	2.28
0	Apply Roundup and Simazine	6.00	9.90	5.71	14.18	63.5	51.00	15.30	47,272	15,142	47.27	15.14
	Total year 0										53.21	21.08
1	Cultivate (3 times)	6.00	9.90	5.53	9.09	297.0 (3 times)	0	0	6,365	6,365	6.36	6.36
1	Apply Simazine	6.00	9.90	5.71	14.18	63.5	6.00	1.80	6,772	2,992	6.77	2.99
	Total year 1										13.13	9.35
2	Apply Simazine	6.00	9.90	5.71	14.18	63.5	6.00	1.80	6,772	2,992	6.77	2.99
	Total year 2										6.77	2.99

[1]Gal/hour = 0.044 gal/hp × 225hp = 9.9 gal/hour.
At $1/gal for diesel fuel, cost/hour = $9.90.

[2]See table 6.

[3]Source: Benson, F. J. 1979. Machinery cost estimates. Unpublished data on file at Agricultural Extension Service, University of Minnesota, St. Paul, Minnesota.

[4]Production rate computed on 900 workable acres.

[5]Current price for Roundup is $60/gal and for Simazine is $2.40/lb.

Table 6.—*Repair costs for site preparation and establishment equipment*

Equipment	Amount of repairs over lifetime in relation to new cost[1]	New cost	Available hours/year	Repair cost/year	Repair cost/hour
	Percent				
225 hp tractor	100	$49,040[2]	1,200	$4,904	$4.09
10 bottom plow	120	13,870[2]	250	1,664	6.66
23-foot offset disk	120	11,290[2]	250	1,355	5.41
30-foot sprayer	100	1,940[2]	120	1,940	1.62
20-foot Lilliston cultivator	120	3,000[3]	250	360	1.44
Planter	120	2,000[3]	250	240	.96

[1]Source: American Society of Agricultural Engineers, 1976 Agricultural Engineering Yearbook, p. 329.
[2]Source: Benson, F. J. 1979. Machinery cost estimates. Unpublished data on file at Agricultural Extension Service, University of Minnesota, St. Paul, Minnesota.
[3]Authors' estimate.

Materials cost per planted acre comes to $208 for the close spacing and $52 for the wide spacing. Due to the slower rate of production, fuel, labor, and repair costs are also higher for the close spacing. As shown in the following tabulation, total operating costs for planting are $221.94/project acre for the 4- by 4-foot spacing and $59.83/project acre for the 8- by 8-foot spacing.

Item	4- by 4-foot spacing	8- by 8-foot spacing
Equipment	3 225 hp tractors 6 planters	2 tractors 4 planters
Equipment cost/hour (for each equipment group)		
Labor[4]	$14.00	$14.00
Fuel	9.90	9.90
Repairs[5]	5.05	5.05
Total equipment cost/hour	28.95	28.95
Production rate (ac/hr)	.75	2.00
Total hours (for all equipment groups)[6]	1,200	450
Total equipment cost	$34,740	$13,028
Plant stock cost/acre[7]	$208	$52
Total stock cost	$187,200	$46,800
Total cost	$221,940	$59,828
Cost/acre	$221.94	$59.83

[4]*One equipment operator and two planters.*
[5]*See table 6.*
[6]*Each equipment group (tractor and two planters) works simultaneously; total hours is the additive number of hours for each group.*
[7]*Stock cost estimated to be $80/M—2,600 trees/acre for close spacing and 650 trees/acre for wide spacing.*

Many other types of stock could be used: longer cuttings, soaked cuttings, rooted cuttings, or even 4-foot to 5-foot rooted stock. The planting method and costs would, of course, depend on the type chosen. Most likely a large operation would produce its own stock, though we have assumed that it was purchased elsewhere.

Irrigation

Irrigation is probably the most important, and the most costly, cultural activity involved in intensively growing hybrid poplar. Research predicts high yields using it, but the large capital investment and high operating cost make it uneconomical. On the same site in the Lake States, yields without irrigation may be 50 percent less than those with irrigation. Irrigation may also make the difference between survival and failure in a dry year. In droughty years growth of established plantations may be reduced by 80 to 90 percent without irrigation.

One of the methods recommended for poplar is a traveling gun system. This involves a well and pump that sends water through an aluminum pipe to a rubber hose attached to a traveling sprinkler. The sprinkler propels itself down a lane, dragging the rubber hose as it travels. The sprinkler must be repositioned when it reaches the end of a lane. It can be towed easily with a small tractor. The height of the gun can be adjusted up to 20 feet.

We seriously question whether this system is practical when trees reach 30 feet. For one thing, the gun may not be capable of spraying above the trees. For another, leaves may intercept much of the water and prevent it from reaching the ground. The high humidity may also increase susceptibility to leaf diseases.

For our analysis we will be optimistic and assume that these difficulties will be resolved and that annual irrigation is possible even for the 15 year rotations. Operating costs were based on a system with a 100-foot well, 600 gal/min sprinkler, turbine pump, right-angle drive, diesel power unit, 3,000 feet of 6-inch aluminum pipe, and 660 feet of 4-inch hose (University of Minnesota 1978). Each system would be sufficient to irrigate from 80 to 120 acres/year 10 times for a total of 10 inches/planted acre/year. Ten such systems would be needed. One 40-horse tractor is considered sufficient to move the sprinklers when needed, though, of course, in practice this would depend on the closeness and accessibility of the tracts. Larger systems would be possible for larger tracts, but the operating costs would be similar for the same amount of water applied.

As shown below the largest portion of the annual operating cost of irrigation is due to fuel—$67.65/acre/year or 68 percent of the total annual cost of $99.74, assuming diesel fuel is used at a cost of $1/gal (University of Minnesota 1978).

Item	Dollars/acre[8]
Fuel	$67.65
Pump and motor (lube and repairs)[9]	12.07
Distribution system[10]	11.20
Labor	8.82
Total	$99.74

Fertilization

One hundred pounds of nitrogen/acre/year are applied in liquid form (28 percent solution) in the irrigation water. We have considered only the annual cost of the material ($80/ton = $14.29/irrigated acre = $12.86/project acre) because the labor cost involved is probably small. Of course, other nutrients may be desirable in practice and other methods of application are possible.

Whole-tree harvesting

Harvesting intensively cultured wood is a new and untried concept. Whole-tree chipping, a highly productive, highly mechanized system, appears the most promising for wood larger than 6 inches d.b.h. We assume this method will be used for the 10- and 15-year rotations. In this system trees are severed and accumulated with feller-bunchers then grapple-skidded to a portable chipper that reduces them to chips. The chips are blown into vans for transport to the mill.

Because field trials of whole-tree harvesting of intensively cultured wood are not yet possible, a computer simulation has furnished a rough estimate of harvesting costs (Mattson 1976). The simulation model uses nearly the same yield and spacing assumptions we have. For the 4- by 4-foot spacing, two 70 hp skidders were used, and for the 8- by 8-foot spacing, a single 110 hp skidder was used. For both systems, a tracked feller-buncher and a small chipper were used.

It has been concluded that harvesting costs are dependent on tree size. The 4- by 4-foot spacing produces trees with an average diameter of 6 inches and harvest costs are estimated to be about $18/dry ton (including hauling). Twelve and one-half inch trees are expected from an 8- by 8-foot spacing in 15 years at an estimated cost of $14/dry ton (table 7).

Predicting accurate harvesting costs for intensively grown poplar today would be difficult; predicting them 10 to 30 years from now is nearly impossible. Although they are one of the most significant costs of production, we consider them uncertain.

Table 7.—*Harvest costs*
(In dollars/acre)

Year of harvest	Dry tons/acre[2]		Harvest cost/acre	
	Irrigated	Nonirrigated	Irrigated	Nonirrigated
4- BY 4-FOOT SPACING (1.2- by 1.2-m)[1]				
10	63	31.5	1,134.00	567.00
15	36	18	288.00	144.00
20	36	18	288.00	144.00
25	36	18	288.00	144.00
30	36	18	280.00	144.00
8- BY 8-FOOT SPACING (2.4- by 2.4-m)[3]				
15	94.5	47.25	1,323.00	661.50
30	94.5	47.25	1,323.00	661.50

[1]Harvest costs: whole tree = $18/dry ton (Source: Mattson, J. A. 1976. Harvesting research for maximum yield systems. Unpublished manuscript on file at the North Central Forest Experiment Station, Forestry Sciences Laboratory, Houghton, Michigan) and forage = $8/dry ton (authors' estimate).

[2]From table 4.

[3]Harvest costs: whole tree = $14/dry ton (Source: Mattson, J. A. 1976. Harvesting research for maximum yield systems. Unpublished manuscript on file at the North Central Forest Experiment Station, Forestry Sciences Laboratory, Houghton, Michigan).

[8]*Assuming 1 system per 100 acres.*

[9]*Includes lubrication of pump, drive, power unit estimated as a percentage of fuel costs, and maintenance and repair of these units calculated as a percentage of the initial investment.*

[10]*Includes the cost of the tractor required to move the gun, the cost of operating the power unit on the gun, and cost of the maintenance and repairs of the distibution system estimated as a percentage of initial investment.*

Forage harvesting

Forage-type mechanized harvesting of biomass is still in the development stage. Most proposed systems involve multifunction machines that fell and chip the wood and blow the chips into containers for transport to the landing. We expect that this harvesting method would be appropriate for the 5 year coppice rotations. Our cost estimate of $8/dry ton is not based on any particular equipment but is simply a subjective estimate. This estimate is lower than harvesting costs of conventional systems because of the higher degree of mechanization, but not as low as reported figures that are unjustifiably based on agricultural-type forage harvester operations.

Land cost

Cleared agricultural land in the Lake States close to the mill or plant, purchased at an average cost of $400/acre in 10 tracts of 80 to 120 acres, makes up the land base for this hypothetical plantation. Larger tracts would be more desirable but would be hard to find.

Administrative

A modest estimate of $7,500/year ($7.50/acre) for the first 2 years was based on a $15,000/year manager working during the growing season on the project, supervising employees and directing operations.

Irrigation equipment

The type of irrigation equipment has been described in the section on irrigation operating costs. The purchase price of this equipment is charged to the project when first purchased and when replaced (table 8). Most equipment will need to be replaced within 10 years, though in practice certain items will likely wear out sooner than others (the hoses for instance). Aluminum pipe can be expected to last 20 years and the well 30 years (25 years is recommended).

The entire purchase price is charged in 1 year rather than spread out in annual payments because a series of annual payments of both principal and interest (at 10 percent) would have the same present value as the purchase price for cash flow purposes.

Fixed costs of irrigation equipment could be reduced by a factor of 3 with tracts of 300 acres, the upper limit of acreage that can be served with one irrigation system. However, variable costs might increase if the system is used to capacity.

Equipment for site preparation and planting

Site preparation and planting equipment is leased rather than purchased because it is only used for a couple of years. In an ongoing operation it would be used annually on different plantations, but the entire cost could not be fairly charged to one plantation and accounting for it as a lease is one method of allocating it.

Lease payments were determined by equating the 1979 price of the various pieces of equipment to a series of equal annual payments using a 10 percent interest rate (table 9). The full year's lease payment is charged. For certain operations the equipment is used such a short time that renting would make more sense than leasing but the difference to the project's overall return would be minimal.

Insurance

We assume the lessor would insure site preparation and planting equipment. Therefore, only fire and storm insurance for the above-ground irrigation

Table 8.—*Irrigation equipment purchase schedule*

Equipment	Quantity needed	Year purchased	New price[1]
	No.		
40-hp tractor	1	1	$ 9,590
Wells - 100-foot lift	10	1	119,700
Turbine pumps	10	1	60,280
R-angle drives	10	1	13,490
Diesel power units	10	1	66,400
Aluminum pipes	10	1	54,150
Traveling guns	10	1	65,360
Hoses	10	1	41,800
			$430,770[2]
40-hp tractor	1	10	9,590
Turbine pumps	10	10	60,280
R-angle drives	10	10	13,490
Diesel power units	10	10	66,400
Traveling guns	10	10	65,360
Hoses	10	10	41,800
			$256,920[2]
40-hp tractor	1	20	9,590
Turbine pumps	10	20	60,280
R-angle drives	10	20	13,490
Diesel power units	10	20	66,400
Aluminum pipes	10	20	54,150
Traveling guns	10	20	65,360
Hoses	10	20	41,800
			$311,070[2]

[1]Source: University of Minnesota. 1978. Water sources and irrigation economics. Miscellaneous Report 150-1978, 76 p. Agricultural Experiment Station, St. Paul, Minnesota.

[2]Investment tax credit is 10 percent of the new price.

Table 9.—*Cost of site preparation and planting equipment*

Equipment	Year(s)	Useful life	New price[2]	Lease payment[2]
		Years	*Dollars*	
225 hp tractor	0,1,2	7	$49,040	$10,073.08
10 bottom plow	0	7	13,870	2,848.97
23-foot offset disk	0	7	11,290	2,319.03
30-foot sprayer	0,1,2	5	1,940	511.77
20-foot Lilliston cultivator	1	7	3,000[3]	616.22
Planter	1	5	2,000[3]	527.59

[1]Source: Benson, F. J. 1979. Machinery cost estimates. Unpublished data on file at Agricultural Extension Service, University of Minnesota, St. Paul, Minnesota.

[2]New price = present value of a series of equal annual payments at 10 percent interest rate.

[3]Authors' estimate.

equipment is included. Insurance is estimated at 1 percent of the new price (University of Minnesota 1978). It will increase when equipment is replaced at a higher cost but not with inflation.

Property tax

We assumed a property tax of $4/acre/year, which is a rough estimate of tax rates in the Lake States for this type of land (University of Minnesota 1978).

Product sale

Current market prices for whole tree chips vary with locality. We used $12.50/green ton delivered, or $25/dry ton, inflated at 5 percent annually, as a representative Lake States price.

Income tax

The federal capital gains tax on timber income is charged at 30 percent of the taxable income, which is the product value less costs for harvesting, site preparation, establishment, planting, irrigation, fertilization, and administration. For all rotations after the first, only irrigation, fertilization, and harvesting costs since the last harvest were deducted from product sale returns. For the last year, capital gains from the sale of land were also taxed. No losses were carried forward or tax benefits from losses computed.

APPENDIX 2—CASH FLOWS

CASH FLOW -- 4' X 4' SPACING -- IRRIGATED
FINANCIAL ANALYSIS FOR A 1000 ACRE OPERATIONAL HYBRID POPLAR PLANTATIO
TOTAL PROJECT AREA IS DIVIDED INTO 10 TRACTS OF 80-120 ACRES EACH.
90 PER CENT OF THE TOTAL PROJECT AREA IS PLANTED.
TREES/PLANTED ACRE: 2600 10" UNROOTED CUTTINGS
ROTATIONS: (1) 10 YEAR AND (4) 5 YEAR COPPICE ROTATIONS
YIELD: 7 DRY TONS/PLANTED ACRE/YR. FOR THE 10 YR. ROTATION
8 " " " " " " " 5 " ROTATIONS
IRRIGATION: 10 EFFECTIVE IN./PLANTED ACRE/YEAR
FERTILIZATION: 100 LBS. OF NITROGEN/PLANTED ACRE/YEAR
NOTE: ALL COST FIGURES BELOW ARE IN DOLLARS/PROJECT ACRE

ANALYSIS INPUTS

UNIT OF CURRENCY	DOLLARS	
LAND AREA	1.00	ACRE
PROD. PERIOD	30	
DISCOUNT RATE	10.00	PERCENT
ANNUAL CHANGE IN COSTS	0	PERCENT
ANNUAL CHANGE IN BEN.	0	PERCENT

AMOUNT AND TIMING OF EXPENDIT AND RECEIPTS
DOLLARS/ACRE

INPUT NO.	NAME	AMOUNT	ANN. RATE OF INFL.	YEAR(S)
1	SITE PREP	53.21	5.00	0
1	SITE PREP	13.13	5.00	1
1	SITE PREP	6.77	5.00	2
2	PLANTING	221.94	5.00	1
3	IRRIGATION	99.74	5.00	1 TO 30
4	FERTILIZAT'N	12.86	5.00	1 TO 30
5	WT HARVEST	1134.00	5.00	10
6	FORG.HARVEST	288.00	5.00	15 20 25 30
7	LAND COST	400.00	5.00	0
8	ADMINISTR'TV	7.50	5.00	0 TO 1
9	IRR.EQUIPM'T	430.77	5.00	1
9	IRR.EQUIPM'T	256.92	5.00	10
9	IRR.EQUIPM'T	311.07	5.00	20
10	SP EQUIPM'T	15.75	5.00	0
10	SP EQUIPM'T	33.90	5.00	1
10	SP EQUIPM'T	10.58	5.00	2
11	INSURANCE	2.57	0	1 TO 9
11	INSURANCE	4.18	0	10 TO 19
11	INSURANCE	6.82	0	20 TO 30
12	INCOME TAX	58.28	0	15
12	INCOME TAX	74.39	0	20
12	INCOME TAX	94.94	0	25
12	INCOME TAX	861.74	0	30
13	PROPERTY TAX	4.00	5.00	0 TO 30
14	PRODUCT SALE	1575.00	5.00	10
14	PRODUCT SALE	900.00	5.00	15 20 25 30
15	LAND SALE	400.00	7.00	30
16	INV TAX CRDT	43.08	5.00	1
16	INV TAX CRDT	25.69	5.00	10
16	INV TAX CRDT	31.11	5.00	20

CASH FLOW -- 4′ X 4′ SPACING -- IRRIGATED
FINANCIAL ANALYSIS FOR A 1000 ACRE OPERATIONAL HYBRID POPLAR PLANTATION
TOTAL PROJECT AREA IS DIVIDED INTO 10 TRACTS OF 80-120 ACRES EACH.
90 PER CENT OF THE TOTAL PROJECT AREA IS PLANTED.
TREES/PLANTED ACRE: 2600 10" UNROOTED CUTTINGS
ROTATIONS: (1) 10 YEAR AND (4) 5 YEAR COPPICE ROTATIONS
YIELD: 7 DRY TONS/PLANTED ACRE/YR. FOR THE 10 YR. ROTATION
8 " " " " " " " 5 " ROTATIONS
IRRIGATION: 10 EFFECTIVE IN./PLANTED ACRE/YEAR
FERTILIZATION: 100 LBS. OF NITROGEN/PLANTED ACRE/YEAR
NOTE: ALL COST FIGURES BELOW ARE IN DOLLARS/PROJECT ACRE

INVESTMENT PERFORMANCE MEASURES

DISCOUNT RATE PERCENT	DISCOUNTED NET RECEIPTS
-.3807	-.93
-.3818	-.00
-.3812 (INTERNAL RATE OF RETURN)	

(10.00 PERCENT DISCOUNT RATE)	DOLLARS)ACRE
NET PRESENT WORTH	-2003.82
NET FUTURE WORTH	-34965.47
FUTURE COSTS	79290.68
PRESENT BENEFITS	2540.21
PRESENT COSTS	4544.03
BENEFITS/COSTS	.56

CASH FLOW -- 4' X 4' SPACING -- IRRIGATED
FINANCIAL ANALYSIS FOR A 1000 ACRE OPERATIONAL HYBRID POPLAR PLANTATION
TOTAL PROJECT AREA IS DIVIDED INTO 10 TRACTS OF 80-120 ACRES EACH.
90 PER CENT OF THE TOTAL PROJECT AREA IS PLANTED.
TREES/PLANTED ACRE: 2600 10" UNROOTED CUTTINGS
ROTATIONS: (1) 10 YEAR AND (4) 5 YEAR COPPICE ROTATIONS
YIELD: 7 DRY TONS/PLANTED ACRE/YR. FOR THE 10 YR. ROTATION
8 " " " " " " 5 " ROTATIONS
IRRIGATION: 10 EFFECTIVE IN./PLANTED ACRE/YEAR
FERTILIZATION: 100 LBS. OF NITROGEN/PLANTED ACRE/YEAR
NOTE: ALL COST FIGURES BELOW ARE IN DOLLARS/PROJECT ACRE

SENSITIVITY ANALYSIS

(10.00 PERCENT DISCOUNT RATE)
DOLLARS/ACRE

		CHANGE IN NPW DUE TO A 10.00 PERCENT CHANGE IN
1	SITE PREP	7.19
2	PLANTING	21.19
3	IRRIGATION	157.58
4	FERTILIZAT'N	20.32
5	WT HARVEST	71.22
6	FORG.HARVEST	41.83
7	LAND COST	40.00
8	ADMINISTR'TV	1.47
9	IRR.EQUIPM'T	69.52
10	SP EQUIPM'T	5.77
11	INSURANCE	3.29
12	INCOME TAX	8.32
13	PROPERTY TAX	6.72
14	PRODUCT SALE	229.62
15	LAND SALE	17.45
16	INV TAX CRDT	6.95

CASH FLOW -- 4' X 4' SPACING -- IRRIGATED
FINANCIAL ANALYSIS FOR A 1000 ACRE OPERATIONAL HYBRID POPLAR PLANTATION
TOTAL PROJECT AREA IS DIVIDED INTO 10 TRACTS OF 80-120 ACRES EACH.
90 PER CENT OF THE TOTAL PROJECT AREA IS PLANTED.
TREES/PLANTED ACRE: 2600 10" UNROOTED CUTTINGS
ROTATIONS: (1) 10 YEAR AND (4) 5 YEAR COPPICE ROTATIONS
YIELD: 7 DRY TONS/PLANTED ACRE/YR. FOR THE 10 YR. ROTATION
8 " " " " " " " 5 " ROTATIONS
IRRIGATION: 10 EFFECTIVE IN./PLANTED ACRE/YEAR
FERTILIZATION: 100 LBS. OF NITROGEN/PLANTED ACRE/YEAR
NOTE: ALL COST FIGURES BELOW ARE IN DOLLARS/PROJECT ACRE

SENSITIVITY OF INTERNAL RATE OF RETURN

PERCENT CHANGE IN INPUT OR OUTPUT TO RAISE/LOWER
ROR BY 2.000 PERCENT AND NPW BY 2003.82 DOLLARS/ACRE

		RATE OF RETURN		PRESENT NET WORTH	
		UPPER THRESHOLD	LOWER THRESHOLD	UPPER THRESHOLD	LOWER THRESHOLD
		1.62	-2.38	0	-4007.64
	INPUT/OUTPUT				
1	SITE PREP	-1620.88	3317.91	-2786.50	2786.50
2	PLANTING	-523.07	1044.70	-945.86	945.86
3	IRRIGATION	-23.19	22.23	-127.17	127.17
4	FERTILIZAT'N	-179.90	172.44	-986.28	986.28
5	WT HARVEST	-76.25	106.10	-281.37	281.37
6	FORG.HARVEST	-49.03	38.71	-479.08	479.08
7	LAND COST	-299.88	623.48	-500.96	500.96
8	ADMINISTR'TV	-7866.01	16020.45	-13669.47	13669.47
9	IRR.EQUIPM'T	-85.67	106.92	-288.23	288.23
10	SP EQUIPM'T	-1932.43	3869.32	-3469.87	3469.87
11	INSURANCE	-1144.64	1118.31	-6083.96	6083.96
12	INCOME TAX	-172.44	115.82	-2409.68	2409.68
13	PROPERTY TAX	-567.42	549.50	-2982.12	2982.12
14	PRODUCT SALE	12.20	-10.66	87.27	-87.27
15	LAND SALE	63.78	-39.75	1148.33	-1148.33
16	INV TAX CRDT	856.68	-1069.19	2882.16	-2882.16

CASH FLOW -- 4' X 4' SPACING -- NON-IRRIGATED
FINANCIAL ANALYSIS FOR A 1000 ACRE OPERATIONAL HYBRID POPLAR PLANTATION
TOTAL PROJECT AREA IS DIVIDED INTO 10 TRACTS OF 80-120 ACRES EACH.
90 PER CENT OF TH TOTAL PROJECT ACREAGE IS PLANTED.
TREES/PLANTED ACRE: 2600 10" UNROOTED CUTTINGS
ROTATIONS: (1) 10 YEAR AND (4) 5 YEAR COPPICE ROTATIONS
YIELD: 3.5 DRY TONS/PLANTED ACRE/YR. FOR THE 10 YR. ROTATION
4 " " " " " " 5 " ROTATIONS
IRRIGATION: NONE
FERTILIZATION: NONE
NOTE: ALL COST FIGURES BELOW ARE IN DOLLARS/PROJECT ACRE.

ANALYSIS INPUTS

UNIT OF CURRENCY	DOLLARS	
LAND AREA	1.00	ACRE
PROD. PERIOD	30	
DISCOUNT RATE	10.00	PERCENT
ANNUAL CHANGE IN COSTS	0	PERCENT
ANNUAL CHANGE IN BEN.	0	PERCENT

AMOUNT AND TIMING OF EXPENDIT AND RECEIPTS
DOLLARS/ACRE

INPUT NO.	NAME	AMOUNT	ANN. RATE OF INFL.	YEAR(S)
1	SITE PREP	53.21	5.00	0
1	SITE PREP	13.13	5.00	1
1	SITE PREP	6.77	5.00	2
2	PLANTING	221.94	5.00	1
3	WT HARVEST	567.00	5.00	10
4	FORG.HARVEST	144.00	5.00	15 20 25 30
5	LAND COST	400.00	5.00	0
6	ADMINISTR'TV	7.50	5.00	0 TO 1
7	SP EQUIPM'T	15.75	5.00	0
7	SP EQUIPM'T	33.90	5.00	1
7	SP EQUIPM'T	10.58	5.00	2
8	INCOME TAX	10.16	0	10
8	INCOME TAX	178.12	0	15
8	INCOME TAX	227.33	0	20
8	INCOME TAX	290.14	0	25
8	INCOME TAX	1110.88	0	30
9	PROPERTY TAX	4.00	5.00	0 TO 30
10	PRODUCT SALE	787.50	5.00	10
10	PRODUCT SALE	450.00	5.00	15 20 25 30
11	LAND SALE	400.00	7.00	30

CASH FLOW -- 4′ X 4′ SPACING -- NON-IRRIGATED
FINANCIAL ANALYSIS FOR A 1000 ACRE OPERATIONAL HYBRID POPLAR PLANTATION
TOTAL PROJECT AREA IS DIVIDED INTO 10 TRACTS OF 80-120 ACRES EACH.
90 PER CENT OF TH TOTAL PROJECT ACREAGE IS PLANTED.
TREES/PLANTED ACRE: 2600 10" UNROOTED CUTTINGS
ROTATIONS: (1) 10 YEAR AND (4) 5 YEAR COPPICE ROTATIONS
YIELD: 3.5 DRY TONS/PLANTED ACRE/YR. FOR THE 10 YR. ROTATION
4 " " " " " " 5 " ROTATIONS
IRRIGATION: NONE
FERTILIZATION: NONE
NOTE: ALL COST FIGURES BELOW ARE IN DOLLARS/PROJECT ACRE.

INVESTMENT PERFORMANCE MEASURES

DISCOUNT RATE PERCENT	DISCOUNTED NET RECEIPTS
8.1174	-.07
8.1169	.00
8.1171 (INTERNAL RATE OF RETURN)	

(10.00 PERCENT DISCOUNT RATE)	DOLLARS)ACRE
NET PRESENT WORTH	-236.78
NET FUTURE WORTH	-4131.60
FUTURE COSTS	27210.08
PRESENT BENEFITS	1322.59
PRESENT COSTS	1559.37
BENEFITS/COSTS	.85

CASH FLOW -- 4' X 4' SPACING -- NON-IRRIGATED
FINANCIAL ANALYSIS FOR A 1000 ACRE OPERATIONAL HYBRID POPLAR PLANTATION
TOTAL PROJECT AREA IS DIVIDED INTO 10 TRACTS OF 80-120 ACRES EACH.
90 PER CENT OF TH TOTAL PROJECT ACREAGE IS PLANTED.
TREES/PLANTED ACRE: 2600 10" UNROOTED CUTTINGS
ROTATIONS: (1) 10 YEAR AND (4) 5 YEAR COPPICE ROTATIONS
YIELD: 3.5 DRY TONS/PLANTED ACRE/YR. FOR THE 10 YR. ROTATION
4 " " " " " " 5 " ROTATIONS
IRRIGATION: NONE
FERTILIZATION: NONE
NOTE: ALL COST FIGURES BELOW ARE IN DOLLARS/PROJECT ACRE.

SENSITIVITY ANALYSIS

(10.00 PERCENT DISCOUNT RATE)
DOLLARS/ACRE

		CHANGE IN NPW DUE TO A 10.00 PERCENT CHANGE IN
1	SITE PREP	7.19
2	PLANTING	21.19
3	WT HARVEST	35.61
4	FORG.HARVEST	20.91
5	LAND COST	40.00
6	ADMINISTR'TV	1.47
7	SP EQUIPM'T	5.77
8	INCOME TAX	17.08
9	PROPERTY TAX	6.72
10	PRODUCT SALE	114.81
11	LAND SALE	17.45

CASH FLOW -- 4' X 4' SPACING -- NON-IRRIGATED
FINANCIAL ANALYSIS FOR A 1000 ACRE OPERATIONAL HYBRID POPLAR PLANTATION
TOTAL PROJECT AREA IS DIVIDED INTO 10 TRACTS OF 80-120 ACRES EACH.
90 PER CENT OF TH TOTAL PROJECT ACREAGE IS PLANTED.
TREES/PLANTED ACRE: 2600 10" UNROOTED CUTTINGS
ROTATIONS: (1) 10 YEAR AND (4) 5 YEAR COPPICE ROTATIONS
YIELD: 3.5 DRY TONS/PLANTED ACRE/YR. FOR THE 10 YR. ROTATION
4 " " " " " " 5 " ROTATIONS
IRRIGATION: NONE
FERTILIZATION: NONE
NOTE: ALL COST FIGURES BELOW ARE IN DOLLARS/PROJECT ACRE.

SENSITIVITY OF INTERNAL RATE OF RETURN

PERCENT CHANGE IN INPUT OR OUTPUT TO RAISE/LOWER
ROR BY 2.000 PERCENT AND NPW BY 236.78 DOLLARS/ACRE

		RATE OF RETURN		PRESENT NET WORTH	
		UPPER THRESHOLD	LOWER THRESHOLD	UPPER THRESHOLD	LOWER THRESHOLD
		10.12	6.12	0	-473.55
	INPUT/OUTPUT				
1	SITE PREP	-345.44	553.83	-329.26	329.26
2	PLANTING	-117.34	183.68	-111.76	111.76
3	WT HARVEST	-70.48	79.08	-66.49	66.49
4	FORG.HARVEST	-121.43	88.70	-113.22	113.22
5	LAND COST	-62.08	100.84	-59.19	59.19
6	ADMINISTR'TV	-1694.84	2703.28	-1615.22	1615.22
7	SP EQUIPM'T	-430.41	676.19	-410.01	410.01
8	INCOME TAX	-149.00	100.61	-138.64	138.64
9	PROPERTY TAX	-374.05	379.55	-352.37	352.37
10	PRODUCT SALE	22.01	-18.94	20.62	-20.62
11	LAND SALE	146.92	-78.65	135.69	-135.69

CASH FLOW -- 8' X 8' SPACING -- IRRIGATED
FINANCIAL ANALYSIS FOR A 1000 ACRE OPERATIONAL HYBRID POPLAR PLANTATION
TOTAL PROJECT ACREAGE IS DIVIDED INTO 10 TRACTS OF 80-120 ACRES EACH.
90 PER CENT OF THE TOTAL PROJECT ACREAGE IS PLANTED.
TREES/PLANTED ACRE: 650 10" UNROOTED CUTTINGS
ROTATIONS: (2) 15 YEAR
YIELD: 7 DRY TONS/PLANTED ACRE/YR. FOR EACH ROTATION
IRRIGATION: 10 EFFECTIVE IN./PLANTED ACRE/YEAR
FERTILIZATION: 100 LBS. OF NITROGEN/PLANTED ACRE/YEAR
NOTE: ALL COST FIGURES BELOW ARE IN DOLLARS/PROJECT ACRE.

ANALYSIS INPUTS

UNIT OF CURRENCY	DOLLARS	
LAND AREA	1.00	ACRE
PROD. PERIOD	30	
DISCOUNT RATE	10.00	PERCENT
ANNUAL CHANGE IN COSTS	0	PERCENT
ANNUAL CHANGE IN BEN.	0	PERCENT

AMOUNT AND TIMING OF EXPENDIT AND RECEIPTS
DOLLARS/ACRE

INPUT NO.	NAME	AMOUNT	ANN. RATE OF INFL.	YEAR(S)
1	SITE PREP	21.08	5.00	0
1	SITE PREP	9.35	5.00	1
1	SITE PREP	2.99	5.00	2
2	PLANTING	59.83	5.00	1
3	IRRIGATION	99.74	5.00	1 TO 30
4	FERTILIZAT'N	12.86	5.00	1 TO 30
5	WT HARVEST	1323.00	5.00	15 30
6	LAND COST	400.00	5.00	0
7	ADMINISTR'TV	7.50	5.00	0 TO 1
8	IRR.EQUIPM'T	430.77	5.00	1
8	IRR.EQUIPM'T	256.92	5.00	10
8	IRR.EQUIPM'T	311.07	5.00	20
9	SP EQUIPM'T	15.75	5.00	0
9	SP EQUIPM'T	22.77	5.00	1
9	SP EQUIPM'T	10.58	5.00	2
10	INSURANCE	2.57	0	1 TO 9
10	INSURANCE	4.18	0	10 TO 19
10	INSURANCE	6.82	0	20 TO 30
11	INCOME TAX	740.57	0	30
12	PROPERTY TAX	4.00	5.00	0 TO 30
13	PRODUCT SALE	2362.50	5.00	15 30
14	LAND SALE	400.00	7.00	30
15	INV TAX CRDT	43.08	5.00	1
15	INV TAX CRDT	25.69	5.00	10
15	INV TAX CRDT	31.11	5.00	20

CASH FLOW -- 8' X 8' SPACING -- IRRIGATED
FINANCIAL ANALYSIS FOR A 1000 ACRE OPERATIONAL HYBRID POPLAR PLANTATION
TOTAL PROJECT ACREAGE IS DIVIDED INTO 10 TRACTS OF 80-120 ACRES EACH.
90 PER CENT OF THE TOTAL PROJECT ACREAGE IS PLANTED.
TREES/PLANTED ACRE: 650 10" UNROOTED CUTTINGS
ROTATIONS: (2) 15 YEAR
YIELD: 7 DRY TONS/PLANTED ACRE/YR. FOR EACH ROTATION
IRRIGATION: 10 EFFECTIVE IN./PLANTED ACRE/YEAR
FERTILIZATION: 100 LBS. OF NITROGEN/PLANTED ACRE/YEAR
NOTE: ALL COST FIGURES BELOW ARE IN DOLLARS/PROJECT ACRE.

INVESTMENT PERFORMANCE MEASURES

DISCOUNT RATE PERCENT	DISCOUNTED NET RECEIPTS
-1.6122	.53
-1.6117	-.00
-1.6120 (INTERNAL RATE OF RETURN)	

(10.00 PERCENT DISCOUNT RATE)	DOLLARS)ACRE
NET PRESENT WORTH	-2149.51
NET FUTURE WORTH	-37507.75
FUTURE COSTS	72492.83
PRESENT BENEFITS	2004.94
PRESENT COSTS	4154.46
BENEFITS/COSTS	.48

CASH FLOW -- 8' X 8' SPACING -- IRRIGATED
FINANCIAL ANALYSIS FOR A 1000 ACRE OPERATIONAL HYBRID POPLAR PLANTATION
TOTAL PROJECT ACREAGE IS DIVIDED INTO 10 TRACTS OF 80-120 ACRES EACH.
90 PER CENT OF THE TOTAL PROJECT ACREAGE IS PLANTED.
TREES/PLANTED ACRE: 650 10" UNROOTED CUTTINGS
ROTATIONS: (2) 15 YEAR
YIELD: 7 DRY TONS/PLANTED ACRE/YR. FOR EACH ROTATION
IRRIGATION: 10 EFFECTIVE IN./PLANTED ACRE/YEAR
FERTILIZATION: 100 LBS. OF NITROGEN/PLANTED ACRE/YEAR
NOTE: ALL COST FIGURES BELOW ARE IN DOLLARS/PROJECT ACRE.

SENSITIVITY ANALYSIS

(10.00 PERCENT DISCOUNT RATE)
DOLLARS/ACRE

		CHANGE IN NPW DUE TO A 10.00 PERCENT CHANGE IN
1	SITE PREP	3.27
2	PLANTING	5.71
3	IRRIGATION	157.58
4	FERTILIZAT'N	20.32
5	WT HARVEST	98.61
6	LAND COST	40.00
7	ADMINISTR'TV	1.47
8	IRR.EQUIPM'T	69.52
9	SP EQUIPM'T	4.71
10	INSURANCE	3.29
11	INCOME TAX	4.24
12	PROPERTY TAX	6.72
13	PRODUCT SALE	176.09
14	LAND SALE	17.45
15	INV TAX CRDT	6.95

CASH FLOW -- 8′ X 8′ SPACING -- IRRIGATED
FINANCIAL ANALYSIS FOR A 1000 ACRE OPERATIONAL HYBRID POPLAR PLANTATION
TOTAL PROJECT ACREAGE IS DIVIDED INTO 10 TRACTS OF 80-120 ACRES EACH.
90 PER CENT OF THE TOTAL PROJECT ACREAGE IS PLANTED.
TREES/PLANTED ACRE: 650 10" UNROOTED CUTTINGS
ROTATIONS: (2) 15 YEAR
YIELD: 7 DRY TONS/PLANTED ACRE/YR. FOR EACH ROTATION
IRRIGATION: 10 EFFECTIVE IN./PLANTED ACRE/YEAR
FERTILIZATION: 100 LBS. OF NITROGEN/PLANTED ACRE/YEAR
NOTE: ALL COST FIGURES BELOW ARE IN DOLLARS/PROJECT ACRE.

SENSITIVITY OF INTERNAL RATE OF RETURN

PERCENT CHANGE IN INPUT OR OUTPUT TO RAISE/LOWER
ROR BY 2.000 PERCENT AND NPW BY 2149.51 DOLLARS/ACRE

		RATE OF RETURN		PRESENT NET WORTH	
		UPPER THRESHOLD	LOWER THRESHOLD	UPPER THRESHOLD	LOWER THRESHOLD
		.39	-3.61	0	-4299.03
	INPUT/OUTPUT				
1	SITE PREP	-4753.20	10811.18	-6567.54	6567.54
2	PLANTING	-2592.41	5774.79	-3763.79	3763.79
3	IRRIGATION	-25.09	25.73	-136.41	136.41
4	FERTILIZAT′N	-194.57	199.52	-1057.99	1057.99
5	WT HARVEST	-21.11	17.10	-217.98	217.98
6	LAND COST	-405.57	940.94	-537.38	537.38
7	ADMINISTR′TV	-10572.44	24018.70	-14663.36	14663.36
8	IRR.EQUIPM′T	-100.33	134.59	-309.18	309.18
9	SP EQUIPM′T	-3172.23	7086.79	-4561.30	4561.30
10	INSURANCE	-1244.96	1302.11	-6526.31	6526.31
11	INCOME TAX	-246.05	168.56	-5064.71	5064.71
12	PROPERTY TAX	-616.03	637.11	-3198.94	3198.94
13	PRODUCT SALE	11.82	-9.57	122.07	-122.07
14	LAND SALE	59.84	-41.00	1231.82	-1231.82
15	INV TAX CRDT	1003.23	-1345.84	3091.71	-3091.71

CASH FLOW -- 8' X 8' SPACING -- NON-IRRIGATED
FINANCIAL ANALYSIS FOR A 1000 ACRE OPERATIONAL HYBRID POPLAR PLANTATION
TOTAL PROJECT ACREAGE IS DIVIDED INTO 10 TRACTS OF 80-120 ACRES EACH.
90 PER CENT OF THE TOTAL PROJECT ACREAGE IS PLANTED.
TREES/PLANTED ACRE: 650 10" UNROOTED CUTTINGS
ROTATIONS: (2) 15 YEAR
YIELD: 3.5 DRY TONS/PLANTED ACRE/YR. FOR EACH ROTATION
IRRIGATION: 10 EFFECTIVE IN./PLANTED ACRE/YEAR
FERTILIZATION: 100 LBS./PLANTED ACRE/YEAR OF NITROGEN
NOTE: ALL COST FIGURES BELOW ARE IN DOLLARS/PROJECT ACRE.

ANALYSIS INPUTS

UNIT OF CURRENCY	DOLLARS	
LAND AREA	1.00	ACRE
PROD. PERIOD	30	
DISCOUNT RATE	10.00	PERCENT
ANNUAL CHANGE IN COSTS	0	PERCENT
ANNUAL CHANGE IN BEN.	0	PERCENT

AMOUNT AND TIMING OF EXPENDIT AND RECEIPTS
DOLLARS/ACRE

INPUT NO.	NAME	AMOUNT	ANN. RATE OF INFL.	YEAR(S)
1	SITE PREP	21.08	5.00	0
1	SITE PREP	9.35	5.00	1
1	SITE PREP	2.99	5.00	2
2	PLANTING	59.83	5.00	1
3	WT HARVEST	661.50	5.00	15 30
4	LAND COST	400.00	5.00	0
5	ADMINISTR'TV	7.50	5.00	0 TO 1
6	SP EQUIPM'T	15.75	5.00	0
6	SP EQUIPM'T	22.77	5.00	1
6	SP EQUIPM'T	10.58	5.00	2
7	INCOME TAX	271.08	0	15
7	INCOME TAX	1369.54	0	30
8	PROPERTY TAX	4.00	5.00	0 TO 30
9	PRODUCT SALE	1181.25	5.00	15 30
10	LAND SALE	400.00	7.00	30

CASH FLOW -- 8′ X 8′ SPACING -- NON-IRRIGATED
FINANCIAL ANALYSIS FOR A 1000 ACRE OPERATIONAL HYBRID POPLAR PLANTATION
TOTAL PROJECT ACREAGE IS DIVIDED INTO 10 TRACTS OF 80-120 ACRES EACH.
90 PER CENT OF THE TOTAL PROJECT ACREAGE IS PLANTED.
TREES/PLANTED ACRE: 650 10" UNROOTED CUTTINGS
ROTATIONS: (2) 15 YEAR
YIELD: 3.5 DRY TONS/PLANTED ACRE/YR. FOR EACH ROTATION
IRRIGATION: 10 EFFECTIVE IN./PLANTED ACRE/YEAR
FERTILIZATION: 100 LBS./PLANTED ACRE/YEAR OF NITROGEN
NOTE: ALL COST FIGURES BELOW ARE IN DOLLARS/PROJECT ACRE.

INVESTMENT PERFORMANCE MEASURES

DISCOUNT RATE PERCENT	DISCOUNTED NET RECEIPTS
8.0555	-.12
8.0545	.00
8.0550 (INTERNAL RATE OF RETURN)	

(10.00 PERCENT DISCOUNT RATE)	DOLLARS)ACRE
NET PRESENT WORTH	-200.30
NET FUTURE WORTH	-3495.08
FUTURE COSTS	21903.48
PRESENT BENEFITS	1054.96
PRESENT COSTS	1255.26
BENEFITS/COSTS	.84

CASH FLOW -- 8' X 8' SPACING -- NON-IRRIGATED
FINANCIAL ANALYSIS FOR A 1000 ACRE OPERATIONAL HYBRID POPLAR PLANTATION
TOTAL PROJECT ACREAGE IS DIVIDED INTO 10 TRACTS OF 80-120 ACRES EACH.
90 PER CENT OF THE TOTAL PROJECT ACREAGE IS PLANTED.
TREES/PLANTED ACRE: 650 10" UNROOTED CUTTINGS
ROTATIONS: (2) 15 YEAR
YIELD: 3.5 DRY TONS/PLANTED ACRE/YR. FOR EACH ROTATION
IRRIGATION: 10 EFFECTIVE IN./PLANTED ACRE/YEAR
FERTILIZATION: 100 LBS./PLANTED ACRE/YEAR OF NITROGEN
NOTE: ALL COST FIGURES BELOW ARE IN DOLLARS/PROJECT ACRE.

SENSITIVITY ANALYSIS

(10.00 PERCENT DISCOUNT RATE)
DOLLARS/ACRE

		CHANGE IN NPW DUE TO A 10.00 PERCENT CHANGE IN
1	SITE PREP	3.27
2	PLANTING	5.71
3	WT HARVEST	49.31
4	LAND COST	40.00
5	ADMINISTR'TV	1.47
6	SP EQUIPM'T	4.71
7	INCOME TAX	14.34
8	PROPERTY TAX	6.72
9	PRODUCT SALE	88.05
10	LAND SALE	17.45

CASH FLOW -- 8' X 8' SPACING -- NON-IRRIGATED
FINANCIAL ANALYSIS FOR A 1000 ACRE OPERATIONAL HYBRID POPLAR PLANTATION
TOTAL PROJECT ACREAGE IS DIVIDED INTO 10 TRACTS OF 80-120 ACRES EACH.
90 PER CENT OF THE TOTAL PROJECT ACREAGE IS PLANTED.
TREES/PLANTED ACRE: 650 10" UNROOTED CUTTINGS
ROTATIONS: (2) 15 YEAR
YIELD: 3.5 DRY TONS/PLANTED ACRE/YR. FOR EACH ROTATION
IRRIGATION: 10 EFFECTIVE IN./PLANTED ACRE/YEAR
FERTILIZATION: 100 LBS./PLANTED ACRE/YEAR OF NITROGEN
NOTE: ALL COST FIGURES BELOW ARE IN DOLLARS/PROJECT ACRE.

SENSITIVITY OF INTERNAL RATE OF RETURN

PERCENT CHANGE IN INPUT OR OUTPUT TO RAISE/LOWER
ROR BY 2.000 PERCENT AND NPW BY 200.30 DOLLARS/ACRE

		RATE OF RETURN		PRESENT NET WORTH	
		UPPER THRESHOLD	LOWER THRESHOLD	UPPER THRESHOLD	LOWER THRESHOLD
		10.06	6.06	0	-400.60
	INPUT/OUTPUT				
1	SITE PREP	-625.42	1034.46	-611.98	611.98
2	PLANTING	-358.52	580.98	-350.72	350.72
3	WT HARVEST	-41.92	32.48	-40.62	40.62
4	LAND COST	-51.16	86.04	-50.07	50.07
5	ADMINISTR'TV	-1396.41	2305.76	-1366.37	1366.37
6	SP EQUIPM'T	-434.46	707.18	-425.03	425.03
7	INCOME TAX	-144.40	99.18	-139.70	139.70
8	PROPERTY TAX	-306.30	321.15	-298.09	298.09
9	PRODUCT SALE	23.48	-18.19	22.75	-22.75
10	LAND SALE	119.05	-65.93	114.78	-114.78

APPENDIX 3—DISCUSSION OF ENERGY ANALYSIS

Only direct energy expenditures (fuel and chemicals) were considered in the energy analysis. Energy expended in manufacturing equipment and in labor was not considered because it is an insignificant part of the total energy picture.

Preparing Site and Establishing Trees

Energy inputs for preparing the site and establishing the trees include fuel and herbicides. Fuel energy was calculated from the total hours spent and the fuel consumption rates/hour (table 5), using a conversion factor of 0.138 MMBTU's/gal. of diesel. Herbicides were estimated to contain 11,000 kcal/lb (Eidman *et al.* 1975).

Planting, Irrigating

Fuel was the only energy input accounted for in planting and irrigating and was calculated in the same way as above, using information from Appendix 1.

Fertilizing

Energy content of nitrogen fertilizer was estimated to be 8,400 kcal/lb, or for 100 lbs/acre, 3.33 MMBTU's /acre (Eidman *et al.* 1975).

Whole Tree and Forage Harvesting

Fuel consumption/dry ton was estimated using information from the simulation of a whole tree harvesting system for intensively grown poplar[11]. For lack of a better estimate, we assumed that forage harvesting would take the same amount of energy (table 10).

Table 10.—*Harvesting energy expenditures*[1]

Machine	Trees harvested			Diesel fuel used	
	4- by 4-foot spacing	8- by 8-foot spacing		4- by 4-foot spacing	8- by 8-foot spacing
	Green tons/hr		*Gal/hr*	*Gal/green ton*	
Medium skidder	—	14.7	3.30	—	0.224
Small skidders(2)	12.4	—	4.20	0.339	—
Feller-buncher	21.2	70.3	4.71	.222	.067
Chipper/baler	12.4	14.7	7.65	.617	.520
			Total	1.178	.811
			Gal/dry ton	2.356	1.622

[1]Source: Mattson, J. A. 1976. Harvesting research for maximum yield systems. Unpublished report on file at North Central Forest Experiment Station, Forestry Sciences Laboratory, Houghton, Michigan.

[11]*Mattson, J. A. 1976. Harvesting research for maximum yield systems. Unpublished report on file at the North Central Forest Experiment Station, Forestry Sciences Laboratory, Houghton, Michigan.*

Hauling

A 50-mile round trip over 10 miles of good gravel road and 15 miles of average paved road using a 40-foot van holding 12 dry tons of chips was used to estimate fuel consumption/dry ton. Hauling energy expenditures were as follows[12]:

25 mile haul (one way)—

loaded:	10 miles class II county roads × 0.276 gal/mile =	2.76 gal
unloaded:	10 miles class II county roads × 0.110 gal/mile =	1.10 gal
loaded:	15 miles class I paved road × 0.224 gal/mile =	3.36 gal
unloaded:	15 miles class I paved road × 0.120 gal/mile =	1.80 gal
		9.02 gal

Given 12 dry tons/van then 9.02 gals ÷ 12 tons = .75 gal of diesel/dry ton

Drying

An estimated 3.184 MMBTU's/dry ton is used to dry wood chips (Blankenhorn *et al.* 1978).

Wood energy

The gross heat content of hybrid poplar is 16.8 MMBTU's/dry ton, a weighted average of the heat content for stem and branch wood (Zavitkovski 1979). Blankenhorn *et al.* (1978) estimate that 86 percent of this gross heat energy is usable, and that only 35 percent of this is converted into electrical energy. We used gross energy in the energy flow analysis.

[12]*Source: Aube, P. J. 1979. University of Minnesota.*

APPENDIX 4.—DISCOUNTED ENERGY FLOWS

ENERGY BUDGET -- 4' X 4' SPACING -- IRRIGATED
ENERGY ANALYSIS FOR A 1000 ACRE OPERATIONAL HYBRID POPLAR PLANTATION
TOTAL PROJECT ACREAGE IS DIVIDED INTO 10 TRACTS OF 80-120 ACRES EACH.
90 PER CENT OF THE TOTAL PROJECT ACREAGE IS PLANTED.
TREES/PLANTED ACRE: 2600 10" UNROOTED CUTTINGS
ROTATIONS: (1) 10 YEAR AND (4) 5 YEAR COPPICE ROTATIONS
YIELD: 7 DRY TONS/PLANTED ACRE/YR. FOR THE TEN YEAR ROTATION
8 " " " " " " " FIVE YEAR ROTATIONS
IRRIGATION: 10 EFFECTIVE INCHES/PLANTED ACRE/YEAR
FERTILIZATION: 100 LBS. OF NITROGEN/PLANTED ACRE/YEAR
NOTE: ALL ENERGY INPUTS AND OUTPUTS BELOW ARE EXPRESSED IN MMBTU'S/ACRE

ANALYSIS INPUTS

UNIT OF CURRENCY		MMBTU'S
LAND AREA	1.00	ACRE
PROD. PERIOD	30	
DISCOUNT RATE	10.00	PERCENT
ANNUAL CHANGE IN COSTS	0	PERCENT
ANNUAL CHANGE IN BEN.	0	PERCENT

AMOUNT AND TIMING OF COSTS AND BENEFITS
MMBTU'S/ACRE

INPUT NO.	NAME	AMOUNT	ANN. RATE OF INFL.	YEAR(S)
1	SITE PREP	.52	0	0
1	SITE PREP	.59	0	1
1	SITE PREP	.19	0	2
2	PLANTING	1.64	0	1
3	IRRIGATION	9.34	0	1 TO 30
4	FERTILIZAT'N	3.33	0	1 TO 30
5	WT HARVEST	20.47	0	10
6	FORG.HARVEST	11.70	0	15 20 25 30
7	HAULING	6.52	0	10
7	HAULING	3.72	0	15 20 25 30
8	DRYING	200.59	0	10
8	DRYING	114.62	0	15 20 25 30
9	WOOD ENERGY	1058.40	0	10
9	WOOD ENERGY	604.80	0	15 20 25 30

ENERGY BUDGET -- 4' X 4' SPACING -- IRRIGATED
ENERGY ANALYSIS FOR A 1000 ACRE OPERATIONAL HYBRID POPLAR PLANTATION
TOTAL PROJECT ACREAGE IS DIVIDED INTO 10 TRACTS OF 80-120 ACRES EACH.
90 PER CENT OF THE TOTAL PROJECT ACREAGE IS PLANTED.
TREES/PLANTED ACRE: 2600 10" UNROOTED CUTTINGS
ROTATIONS: (1) 10 YEAR AND (4) 5 YEAR COPPICE ROTATIONS
YIELD: 7 DRY TONS/PLANTED ACRE/YR. FOR THE TEN YEAR ROTATION
8 " " " " " " " FIVE YEAR ROTATIONS
IRRIGATION: 10 EFFECTIVE INCHES/PLANTED ACRE/YEAR
FERTILIZATION: 100 LBS. OF NITROGEN/PLANTED ACRE/YEAR
NOTE: ALL ENERGY INPUTS AND OUTPUTS BELOW ARE EXPRESSED IN MMBTU'S/ACRE

(10.00 PERCENT DISCOUNT RATE)	MMBTU'S)ACRE
NET PRESENT WORTH	453.42
NET FUTURE WORTH	7911.98
FUTURE COSTS	4882.34
PRESENT BENEFITS	733.22
PRESENT COSTS	279.80
BENEFITS/COSTS	2.62

ENERGY BUDGET -- 4' X 4' SPACING -- IRRIGATED
ENERGY ANALYSIS FOR A 1000 ACRE OPERATIONAL HYBRID POPLAR PLANTATION
TOTAL PROJECT ACREAGE IS DIVIDED INTO 10 TRACTS OF 80-120 ACRES EACH.
90 PER CENT OF THE TOTAL PROJECT ACREAGE IS PLANTED.
TREES/PLANTED ACRE: 2600 10" UNROOTED CUTTINGS
ROTATIONS: (1) 10 YEAR AND (4) 5 YEAR COPPICE ROTATIONS
YIELD: 7 DRY TONS/PLANTED ACRE/YR. FOR THE TEN YEAR ROTATION
8 " " " " " " " FIVE YEAR ROTATIONS
IRRIGATION: 10 EFFECTIVE INCHES/PLANTED ACRE/YEAR
FERTILIZATION: 100 LBS. OF NITROGEN/PLANTED ACRE/YEAR
NOTE: ALL ENERGY INPUTS AND OUTPUTS BELOW ARE EXPRESSED IN MMBTU'S/ACRE

SENSITIVITY ANALYSIS

(10.00 PERCENT DISCOUNT RATE)
MMBTU'S/ACRE

	DUE TO A 10.00 PERCENT CHANGE IN	CHANGE IN NPW
1	SITE PREP	.12
2	PLANTING	.15
3	IRRIGATION	8.80
4	FERTILIZAT'N	3.14
5	WT HARVEST	.79
6	FORG.HARVEST	.63
7	HAULING	.45
8	DRYING	13.90
9	WOOD ENERGY	73.32

ENERGY BUDGET -- 4' X 4' SPACING -- NON-IRRIGATED
ENERGY ANALYSIS FOR A 1000 ACRE OPERATIONAL HYBRID POPLAR PLANTATION
TOTAL PROJECT ACREAGE IS DIVIDED INTO 10 TRACTS OF 80-120 ACRES EACH.
90 PER CENT OF THE TOTAL PROJECT ACREAGE IS PLANTED.
TREES/PLANTED ACRE: 2600 10" UNROOTED CUTTINGS
ROTATIONS: (1) 10 YEAR AND (4) 5 YEAR COPPICE ROTATIONS
YIELD: 7 DRY TONS/PLANTED ACRE/YR. FOR THE TEN YEAR ROTATION
8 " " " " " " FIVE YEAR ROTATIONS
IRRIGATION: NONE
FERTILIZATION: NONE
NOTE: ALL ENERGY INPUTS AND OUTPUTS BELOW ARE EXPRESSED IN MMBTU'S/ACRE

ANALYSIS INPUTS

UNIT OF CURRENCY	MMBTU'S	
LAND AREA	1.00	ACRE
PROD. PERIOD	30	
DISCOUNT RATE	10.00	PERCENT
ANNUAL CHANGE IN COSTS	0	PERCENT
ANNUAL CHANGE IN BEN.	0	PERCENT

AMOUNT AND TIMING OF COSTS AND BENEFITS
MMBTU'S/ACRE

INPUT NO.	NAME	AMOUNT	ANN. RATE OF INFL.	YEAR(S)
1	SITE PREP	.52	0	0
1	SITE PREP	.59	0	1
1	SITE PREP	.19	0	2
2	PLANTING	1.64	0	1
3	WT HARVEST	10.24	0	10
4	FORG.HARVEST	5.85	0	15 20 25 30
5	HAULING	3.26	0	10
5	HAULING	1.86	0	15 20 25 30
6	DRYING	100.30	0	10
6	DRYING	57.31	0	15 20 25 30
7	WOOD ENERGY	529.20	0	10
7	WOOD ENERGY	302.40	0	15 20 25 30

ENERGY BUDGET -- 4' X 4' SPACING -- NON-IRRIGATED
ENERGY ANALYSIS FOR A 1000 ACRE OPERATIONAL HYBRID POPLAR PLANTATION
TOTAL PROJECT ACREAGE IS DIVIDED INTO 10 TRACTS OF 80-120 ACRES EACH.
90 PER CENT OF THE TOTAL PROJECT ACREAGE IS PLANTED.
TREES/PLANTED ACRE: 2600 10" UNROOTED CUTTINGS
ROTATIONS: (1) 10 YEAR AND (4) 5 YEAR COPPICE ROTATIONS
YIELD: 7 DRY TONS/PLANTED ACRE/YR. FOR THE TEN YEAR ROTATION
8 " " " " " " " FIVE YEAR ROTATIONS
IRRIGATION: NONE
FERTILIZATION: NONE
NOTE: ALL ENERGY INPUTS AND OUTPUTS BELOW ARE EXPRESSED IN MMBTU'S/ACRE

(10.00 PERCENT DISCOUNT RATE)	MMBTU'S)ACRE
NET PRESENT WORTH	285.08
NET FUTURE WORTH	4974.40
FUTURE COSTS	1422.76
PRESENT BENEFITS	366.61
PRESENT COSTS	81.54
BENEFITS/COSTS	4.50

ENERGY BUDGET -- 4' X 4' SPACING -- NON-IRRIGATED
ENERGY ANALYSIS FOR A 1000 ACRE OPERATIONAL HYBRID POPLAR PLANTATION
TOTAL PROJECT ACREAGE IS DIVIDED INTO 10 TRACTS OF 80-120 ACRES EACH.
90 PER CENT OF THE TOTAL PROJECT ACREAGE IS PLANTED.
TREES/PLANTED ACRE: 2600 10" UNROOTED CUTTINGS
ROTATIONS: (1) 10 YEAR AND (4) 5 YEAR COPPICE ROTATIONS
YIELD: 7 DRY TONS/PLANTED ACRE/YR. FOR THE TEN YEAR ROTATION
8 " " " " " " " FIVE YEAR ROTATIONS
IRRIGATION: NONE
FERTILIZATION: NONE
NOTE: ALL ENERGY INPUTS AND OUTPUTS BELOW ARE EXPRESSED IN MMBTU'S/ACRE

SENSITIVITY ANALYSIS

(10.00 PERCENT DISCOUNT RATE)
MMBTU'S/ACRE

	DUE TO A 10.00 PERCENT CHANGE IN	CHANGE IN NPW
1	SITE PREP	.12
2	PLANTING	.15
3	WT HARVEST	.39
4	FORG.HARVEST	.31
5	HAULING	.23
6	DRYING	6.95
7	WOOD ENERGY	36.66

ENERGY BUDGET -- 8' X 8' SPACING -- IRRIGATED
ENERGY ANALYSIS FOR A 1000 ACRE OPERATIONAL HYBRID POPLAR PLANTATION
TOTAL PROJECT ACREAGE IS DIVIDED INTO 10 TRACTS OF 80-120 ACRES EACH.
90 PER CENT OF THE TOTAL PROJECT ACREAGE IS PLANTED.
TREES/PLANTED ACRE: 650 10" UNROOTED CUTTINGS
ROTATIONS: (2) 15 YEAR
YIELD: 7 DRY TONS/PLANTED ACRE/YR. FOR EACH ROTATION
IRRIGATION: 10 EFFECTIVE INCHES/PLANTED ACRE/YEAR
FERTILIZATION: 100 LBS. OF NITROGEN/PLANTED ACRE/YEAR
NOTE: ALL ENERGY INPUTS AND OUTPUTS BELOW ARE EXPRESSED IN MMBTU'S/ACRE

ANALYSIS INPUTS

UNIT OF CURRENCY	MMBTU'S	
LAND AREA	1.00	ACRE
PROD. PERIOD	30	
DISCOUNT RATE	10.00	PERCENT
ANNUAL CHANGE IN COSTS	0	PERCENT
ANNUAL CHANGE IN BEN.	0	PERCENT

AMOUNT AND TIMING OF COSTS AND BENEFITS
MMBTU'S/ACRE

INPUT NO.	NAME	AMOUNT	ANN. RATE OF INFL.	YEAR(S)
1	SITE PREP	.43	0	0
1	SITE PREP	.52	0	1
1	SITE PREP	.12	0	2
2	PLANTING	.61	0	1
3	IRRIGATION	9.34	0	1 TO 30
4	FERTILIZAT'N	3.33	0	1 TO 30
5	WT HARVEST	21.14	0	15 30
6	HAULING	9.78	0	15 30
7	DRYING	300.89	0	15 30
8	WOOD ENERGY	1587.60	0	15 30

ENERGY BUDGET -- 8' X 8' SPACING -- IRRIGATED
ENERGY ANALYSIS FOR A 1000 ACRE OPERATIONAL HYBRID POPLAR PLANTATION
TOTAL PROJECT ACREAGE IS DIVIDED INTO 10 TRACTS OF 80-120 ACRES EACH.
90 PER CENT OF THE TOTAL PROJECT ACREAGE IS PLANTED.
TREES/PLANTED ACRE: 650 10" UNROOTED CUTTINGS
ROTATIONS: (2) 15 YEAR
YIELD: 7 DRY TONS/PLANTED ACRE/YR. FOR EACH ROTATION
IRRIGATION: 10 EFFECTIVE INCHES/PLANTED ACRE/YEAR
FERTILIZATION: 100 LBS. OF NITROGEN/PLANTED ACRE/YEAR
NOTE: ALL ENERGY INPUTS AND OUTPUTS BELOW ARE EXPRESSED IN MMBTU'S/ACRE

(10.00 PERCENT DISCOUNT RATE)	MMBTU'S)ACRE
NET PRESENT WORTH	251.60
NET FUTURE WORTH	4390.24
FUTURE COSTS	3829.16
PRESENT BENEFITS	471.04
PRESENT COSTS	219.44
BENEFITS/COSTS	2.15

ENERGY BUDGET -- 8' X 8' SPACING -- IRRIGATED
ENERGY ANALYSIS FOR A 1000 ACRE OPERATIONAL HYBRID POPLAR PLANTATION
TOTAL PROJECT ACREAGE IS DIVIDED INTO 10 TRACTS OF 80-120 ACRES EACH.
90 PER CENT OF THE TOTAL PROJECT ACREAGE IS PLANTED.
TREES/PLANTED ACRE: 650 10" UNROOTED CUTTINGS
ROTATIONS: (2) 15 YEAR
YIELD: 7 DRY TONS/PLANTED ACRE/YR. FOR EACH ROTATION
IRRIGATION: 10 EFFECTIVE INCHES/PLANTED ACRE/YEAR
FERTILIZATION: 100 LBS. OF NITROGEN/PLANTED ACRE/YEAR
NOTE: ALL ENERGY INPUTS AND OUTPUTS BELOW ARE EXPRESSED IN MMBTU'S/ACRE

SENSITIVITY ANALYSIS

(10.00 PERCENT DISCOUNT RATE)
MMBTU'S/ACRE

		CHANGE IN NPW DUE TO A 10.00 PERCENT CHANGE IN
1	SITE PREP	.10
2	PLANTING	.06
3	IRRIGATION	8.80
4	FERTILIZAT'N	3.14
5	WT HARVEST	.63
6	HAULING	.29
7	DRYING	8.93
8	WOOD ENERGY	47.10

ENERGY BUDGET -- 8′ X 8′ SPACING -- NON-IRRIGATED
ENERGY ANALYSIS FOR A 1000 ACRE OPERATIONAL HYBRID POPLAR PLANTATION
TOTAL PROJECT ACREAGE IS DIVIDED INTO 10 TRACTS OF 80-120 ACRES EACH.
90 PER CENT OF THE TOTAL PROJECT ACREAGE IS PLANTED.
TREES/PLANTED ACRE: 650 10" UNROOTED CUTTINGS
ROTATIONS: (2) 15 YEAR
YIELD: 3.5 DRY TONS/PLANTED ACRE/YR. FOR EACH ROTATION
IRRIGATION: NONE
FERTILIZATION: NONE
NOTE: ALL ENERGY INPUTS AND OUTPUTS BELOW ARE EXPRESSED IN MMBTU′S/ACRE

ANALYSIS INPUTS

UNIT OF CURRENCY	MMBTU′S	
LAND AREA	1.00	ACRE
PROD. PERIOD	30	
DISCOUNT RATE	10.00	PERCENT
ANNUAL CHANGE IN COSTS	0	PERCENT
ANNUAL CHANGE IN BEN.	0	PERCENT

AMOUNT AND TIMING OF COSTS AND BENEFITS
MMBTU′S/ACRE

INPUT NO.	NAME	AMOUNT	ANN. RATE OF INFL.	YEAR(S)
1	SITE PREP	.43	0	0
1	SITE PREP	.52	0	1
1	SITE PREP	.12	0	2
2	PLANTING	.61	0	1
3	WT HARVEST	10.57	0	15 30
4	HAULING	4.89	0	15 30
5	DRYING	150.45	0	15 30
6	WOOD ENERGY	793.80	0	15 30

ENERGY BUDGET -- 8′ X 8′ SPACING -- NON-IRRIGATED
ENERGY ANALYSIS FOR A 1000 ACRE OPERATIONAL HYBRID POPLAR PLANTATION
TOTAL PROJECT ACREAGE IS DIVIDED INTO 10 TRACTS OF 80-120 ACRES EACH.
90 PER CENT OF THE TOTAL PROJECT ACREAGE IS PLANTED.
TREES/PLANTED ACRE: 650 10" UNROOTED CUTTINGS
ROTATIONS: (2) 15 YEAR
YIELD: 3.5 DRY TONS/PLANTED ACRE/YR. FOR EACH ROTATION
IRRIGATION: NONE
FERTILIZATION: NONE
NOTE: ALL ENERGY INPUTS AND OUTPUTS BELOW ARE EXPRESSED IN MMBTU′S/ACRE

(10.00 PERCENT DISCOUNT RATE)	MMBTU′S)ACRE
NET PRESENT WORTH	184.74
NET FUTURE WORTH	3223.58
FUTURE COSTS	886.12
PRESENT BENEFITS	235.52
PRESENT COSTS	50.78
BENEFITS/COSTS	4.64

ENERGY BUDGET -- 8′ X 8′ SPACING -- NON-IRRIGATED
ENERGY ANALYSIS FOR A 1000 ACRE OPERATIONAL HYBRID POPLAR PLANTATION
TOTAL PROJECT ACREAGE IS DIVIDED INTO 10 TRACTS OF 80-120 ACRES EACH.
90 PER CENT OF THE TOTAL PROJECT ACREAGE IS PLANTED.
TREES/PLANTED ACRE: 650 10" UNROOTED CUTTINGS
ROTATIONS: (2) 15 YEAR
YIELD: 3.5 DRY TONS/PLANTED ACRE/YR. FOR EACH ROTATION
IRRIGATION: NONE
FERTILIZATION: NONE
NOTE: ALL ENERGY INPUTS AND OUTPUTS BELOW ARE EXPRESSED IN MMBTU′S/ACRE

SENSITIVITY ANALYSIS

(10.00 PERCENT DISCOUNT RATE)
MMBTU′S/ACRE

		CHANGE IN NPW DUE TO A 10.00 PERCENT CHANGE IN
1	SITE PREP	.10
2	PLANTING	.06
3	WT HARVEST	.31
4	HAULING	.15
5	DRYING	4.46
6	WOOD ENERGY	23.55

☆ U.S. Government Printing Office: 1981—766-984/201

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1981. An economic and energy analysis of poplar intensive cultures in the Lake States. U.S. Department of Agriculture Forest Service, Research Paper NC-196, 44 p. U.S. Department of Agriculture Forest Service, North Central Forest Experiment Station, St. Paul, Minnesota.

Short- (5 to 10 years) and long- (15 years) rotation, irrigated and nonirrigated intensive cultures of hybrid poplar were analyzed economically via cash flow analysis. Energy balances were also calculated for each alternative. Nonirrigated systems offer reasonable economic returns whereas irrigated systems do not. All systems produce more energy than they use as production inputs.

KEY WORDS: Poplar hybrids, cash flow analysis, energy balances, agriforestry, biomass management.